University of Nevada

Reno

The Geology and Mineral Deposits of the Garfield District, Mineral County, Nevada

A thesis submitted in partial fulfillment of the requirements

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by

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ABSTRACT

The Garfield mining district is located in Mineral County, Nevada, 12 miles northwest of the town of Mina. Production of silver, gold, copper and lead between the 1880's and 1940's yielded about $1,500,000.

The bulk of the district consists of rocks of the Luning, Gold Range, and Dunlap Formations in a series of northeasterly trending folds. The folds are cut by high angle faults and intruded by Cretaceous igneous rocks. The remainder of the district is chiefly Tertiary volcanics in the north and west and Quarternary alluvium in the south.

Mineralization in the district is of two types: epithermal silver-gold and igneous metamorphic deposits of copper. High grade silver-gold in the Luning and Gold Range Formations and a small amount of copper in the Dunlap Formation have been mined.

The Garfield district is believed to have limited economic potential. However, three favorable locations for prospecting are suggested.

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INTRODUCTION

The Garfield mining district is located in the Garfield Hills, Mineral County, Nevada (Fig. 1), approximately 12 miles (19 kilometers) northwest of the town of Mina. It appears on the U. S. G. S. 1967 Mable Mountain 7 1/2-minute topographic quadrangle map in T7N, R33E. The section lines are not shown on the map, but the district appears to lie within sections 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22. 23, 24, 25, 26, 27, and 28. The Bureau of Land Management 1967 Mina, Nevada 30-minute quadrangle map shows the Garfield mining district in the above mentioned township, range and sections. Both maps have the positions of the Bluelight and Bataan mines reversed and the Mabel mine labeled Mable mine, but these mines are shown correctly on Plate 1. In recent usage the Garfield district has been combined with several other districts and they now comprise the Gold Range district.

The topography varies from steep, rugged slopes on the north, facing Soda Spring Valley, to more gentle slopes on the south, facing Garfield Flat. Mines and mining properties in the northern part of the district lie at an elevation of about 6,600 feet (1,980 meters), while in the south they lie between 7,100 feet (2,130 meters) and 7,400 feet (2,220 meters). The highest point in the area, Mable Mountain, has an elevation of 8,014 feet (2,404 meters).

The area may be reached from the north by an unimproved road leading south from Nevada State Highway 95, approximately 5 miles

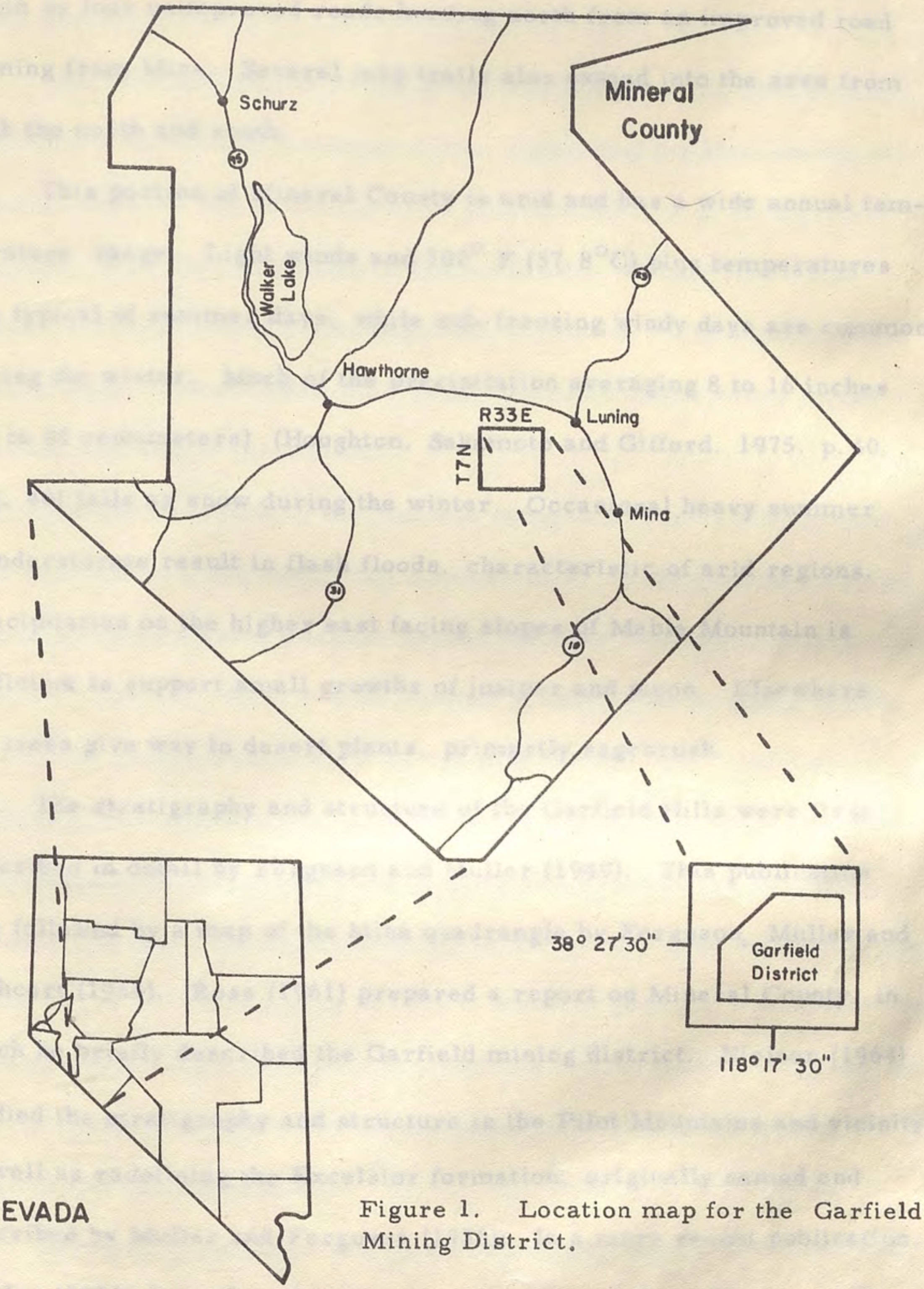

Figure 1. Location map for the Garfield Mining District.

(8 kilometers) west of the town of Luning. It may be reached from the south by four unimproved roads heading north from an improved road coming from Mina. Several jeep trails also extend into the area from both the north and south.

This portion of Mineral County is arid and has a wide annual temperature range. Light winds and 100° F (37.8°C) plus temperatures are typical of summer days, while sub-freezing windy days are common during the winter. Much of the precipitation averaging 8 to 16 inches (20 to 40 centimeters) (Houghton, Sakamoto and Gifford, 1975, p. 40, Fig. 40) falls as snow during the winter. Occasional heavy summer thunderstorms result in flash floods, characteristic of arid regions. Precipitation on the higher east facing slopes of Mable Mountain is sufficient to support small growths of juniper and pinon. Elsewhere the trees give way to desert plants, primarily sagebrush.

The stratigraphy and structure of the Garfield Hills were first described in detail by Ferguson and Muller (1949). This publication was followed by a map of the Mina quadrangle by Ferguson, Muller and Cathcart (1954). Ross (1961) prepared a report on Mineral County, in which he briefly described the Garfield mining district. Nielson (1964) studied the stratigraphy and structure in the Pilot Mountains and vicinity as well as redefining the Excelsior formation, originally named and described by Muller and Ferguson (1936). In a more recent publication, Stanley (1971) describes the tectonic and sedimentologic history of the Dunlap Formation. As is the case with many small, older mining camps in Nevada, information about the economic geology of the district is quite sketchy.

The principal object of this study was to determine what stratigraphic and structural features, if any, controlled the localization of mineral deposits and to estimate the potential for ore of the Garfield district. Work by Ferguson and Muller (1949), Nielson (1964) and Stanley (1971) provided a starting point in relation to the structure and stratigraphy; however very little published information exists on the mineral deposits of the district.

The Garfield mining district was mapped on aerial photographs at a scale of 1:12,000 during the summer of 1975. In general mapping was terminated a short distance beyond the Pre-Tertiary-Tertiary contact. Further, there was no attempt by the author to differentiate or map the post-Jurassic units except in a cursory way. Subsurface geology at the Mendora and Garfield mines and surface geology at the Bataan and Bluelight mines were mapped at a scale of 1:1,200 with Brunton and tape, during the summer of 1975. The area was revisited in the fall of 1975 and spring of 1976 to confirm geologic interpretations. With exception of petrographic descriptions, which traditionally use the metric system, in this report measurements will be given in both the English and metric systems.

Laboratory investigations of some 300 rock specimens collected in the field involved the use of a petrographic microscope, X-ray diffraction, atomic absorption and fire assay methods.

Upon completion of field and laboratory work the geologic characteristics of the mineral deposits in the district were determined through a synthesis of both field and laboratory data. Based on the synthesized data, estimates of ore potential and possible explorations sites were suggested.

Gold and silver were first discovered in the district by Joshua Mass and Amos Everson in 1882. Nearly one-third of the recorded production of gold, silver, was during the 1880's, apparently from the Garfield mine. In 1890 an English company, Hampton Plain Exploration Company, (Vanderburg, 1937, p. 34) purchased the Garfield mine and built a 10 stamp mill at Garfield Springs, 9 miles (14.4 kilometers) south of the mine. During the 1930's lessees ran the material of the mine dumps through screens (Vanderburg, 1937, p. 34) and the fines are reported to have averaged $8.00 per ton in silver and gold.

During the early 1900's the Bluelight Mining Company developed a 600 foot (180 meters) shaft and shipped several car loads of rich copper ore.

Around 1920 Jones and Fitting made six locations covering all known westerly extensions of the Garfield veins (Budelman, 1934), naming the mine, Mabel mine. In 1921 the West End Consolidated Mining Company acquired the Mabel mine, which was a consistent producer of silver and gold during the 1920's. The Mabel mine is reported

(Vanderburg, 1937, p. 35) to have yielded 4,310 tons of ore having a gross value of $421,627, and averaging $97.83 per ton.

Records of the American Smelting and Refining Company, Garfield Plant, Salt Lake City, Utah show that approximately 200 tons of gold-silver ore were shipped from the Mendora mine between August 1938 and April 1939, with a gross value of about $3,500.

The total production from the district is thought to have been worth about 1.5 million dollars; however, the records are incomplete and open to question. Little production has taken place in the district since the 1940's with the exception of a few car loads of silver-gold ore shipped from the Garfield mine dumps in recent years.

REGIONAL GEOLOGY

STRATIGRAPHY

The rocks of the region range in age from Cambrian to Quaternary, but consist primarily of Mesozoic sedimentary and volcanic rocks and Tertiary volcanic rocks. Numerous Cretaceous plutons have intruded the older rocks throughout the region.

Paleozoic rocks in Mineral County, with the exception of the Excelsior Formation discussed later, are limited to an area along the boundary between Mineral and Esmeralda Counties about 20 miles (32 kilometers) south of Mina. These rocks, which comprise the Miller Mountain, Palmetto, and Diablo Formations, consist of marine sediments and have a combined thickness of about 7400 feet (2200 meters) (Ferguson, Muller and Cathcart, 1954). They do not appear in the Garfield district and will not be considered here.

According to Ross (1961, p. 20) the age and correlation of the Excelsior, youngest of the Paleozoic formations in the region, has been a problem ever since it was first defined. Muller and Ferguson (1936, p. 244) named the Excelsior Formation for the Excelsior Mountains about 6 miles (10 kilometers) southwest of Mina. Based on fossils found in the Gillis Range, about 40 miles (64 kilometers) northwest of Mina, they dated the formation as Middle Triassic. However Ferguson and Muller (1949, p. 5) indicate that similar rocks occurring in the Toiyabe Range,

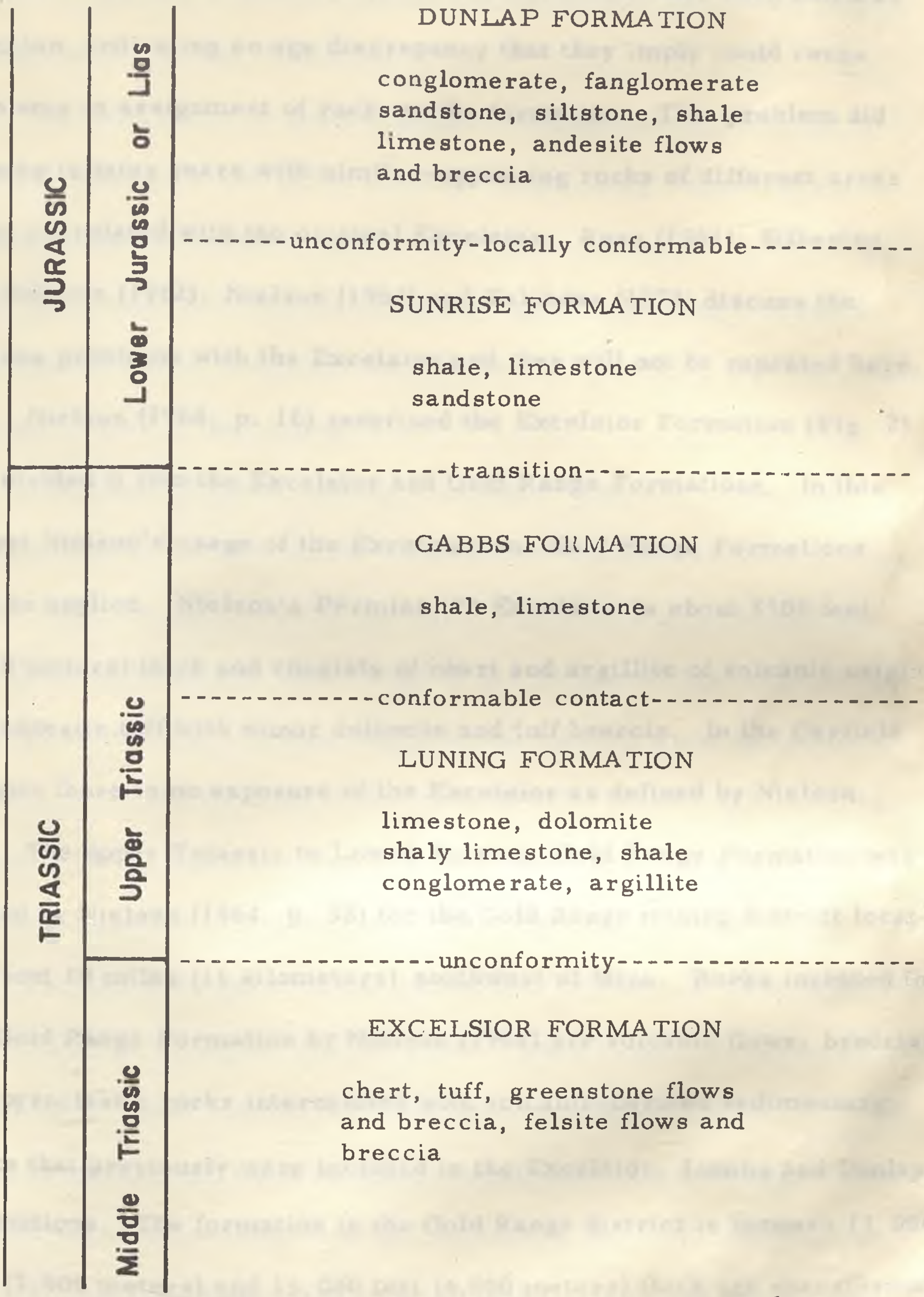

Figure 2. Lower Mesozoic rocks of southeastern Mineral County, Nevada (after Muller and Ferguson, 1939).

about 80 miles (128 kilometers) northeast of Mina, have been dated as Permian, indicating an age discrepancy that they imply could cause problems in assignment of rocks to the formation. This problem did develop in later years with similar-appearing rocks of different areas being correlated with the original Excelsior. Ross (1961), Silbering and Roberts (1962), Nielson (1964) and Talukdar (1972) discuss the various problems with the Excelsior and they will not be repeated here.

Nielson (1964, p. 16) redefined the Excelsior Formation (Fig. 2) and divided it into the Excelsior and Gold Range Formations. In this report Nielson's usage of the Excelsior and Gold Range Formations will be applied. Nielson's Permian (?) Excelsior is about 3500 feet (1050 meters) thick and consists of chert and argillite of volcanic origin and andesite tuff with minor dolomite and tuff breccia. In the Garfield district there is no exposure of the Excelsior as defined by Nielson.

The upper Triassic to Lower Jurassic Gold Range Formation was named by Nielson (1964, p. 38) for the Gold Range mining district located about 10 miles (16 kilometers) southwest of Mina. Rocks included in the Gold Range Formation by Nielson (1964) are volcanic flows, breccias, and pyroclastic rocks intercalated with volcanic-derived sedimentary rocks that previously were included in the Excelsior, Luning and Dunlap Formations. The formation in the Gold Range district is between 13,000 feet (3,900 meters) and 15,000 feet (4,500 meters) thick and unconformably overlies the Excelsior Formation. Nielson (1964, p. 38) suggests that the clastic portion of the Gold Range correlates with the clastic middle member of the Luning Formation.

The Gold Range is present in the Garfield district, forming the oldest, lowest rock unit of the district. The Luning Formation rocks that conformably overlie it in the district are similar to the upper member of the Luning seen elsewhere in the region supporting Nielson's idea that the clastic portion of the Gold Range correlates with the clastic middle member of the Luning.

The Upper Triassic Luning Formation, named by Muller and Ferguson (1936, p. 245) for the settlement of Luning, consists of limestone, dolomite and clastic sediments. It is 8000 feet (2400 meters) thick in the Pilot Range, about 5 miles (8 kilometers) east of Mina, and there unconformably overlies the Excelsior (Muller's and Ferguson's Excelsior). In the Garfield Hills Muller and Ferguson (1939, p. 1595) mention that two slate members are separated by a limestone, and have a combined thickness of 4000 feet to 5000 feet (1200 meters to 1500 meters).

The Upper Triassic Gabbs Formation, (Muller and Ferguson, 1936, p. 248) derives its name from the Gabbs Valley Range. In the New York canyon area, about 7 miles (11 kilometers) northeast of Mina, it is 420 feet (126 meters) thick and consists of dark shale and limestone. There the formation conformably overlies the Luning Formation and is conformably overlain by the Sunrise Formation.

The Lower Jurassic Sunrise Formation, (Muller and Ferguson, 1936, p. 249) derives its name from Sunrise Flat in the Gabbs Valley

Range. about 10 miles (16 kilometers) northeast of Mina. The formation is about 1200 feet (360 meters) thick and consists of shales, limestones, and sandstones. It is overlain unconformably by the Dunlap Formation.

The Lower Jurassic Dunlap Formation was named by Muller and Ferguson (1936, p. 250) and derives its name from Dunlap Canyon in the Pilot Mountains, 5 miles (8 kilometers) east of Mina. There the formation exceeds 5000 feet (1500 meters) and consists of limestone, clastic sediments and volcanic rocks and is overlain unconformably by Tertiary rocks.

Cretaceous granitic rocks, which are chiefly quartz monzonites but range from granodorite to albite granite (Ross, 1961, p. 29), have intruded the older rocks in the region. The similarity of these rocks and those of the Sierra Nevada suggest that they are part of the same batholithic complex (Ross, 1961, p. 30).

Tertiary units within the region are felsic, intermediate and basaltic volcanic rocks. The felsic rocks (Ross, 1961, p. 36) consist of rhyolite and quartz latite welded tuff. Intermediate volcanic rocks (Ross, 1961, p. 36) consist of flows, tuffs and breccias ranging in composition from rhyodacite to andesite, and unconformably overlie the felsic volcanic rocks. An extensive basaltic flow covers a large area of the central and southern part of Mineral County. The volcanic rocks range in age from Miocene to Pliocene, with the felsic being the oldest and the basalt the youngest.

Quaternary deposits consist of older gravels, lake beds, desert wash and alluvium (Ferguson, Muller and Cathcart, 1954). The gravels which are present in all ranges are most abundant at elevations between 5000 feet (1500 meters) and 6500 feet (1950 meters) (Ross, 1961, p. 51) and are considered to indicate an earlier stage of development of the ranges.

STRUCTURE

The structure of the region is quite complex, indicating tectonic activity from at least the Devonian to the present. The region exhibits intense folding, thrust faulting, basin and range faulting and large displacement strike slip faulting.

Work by Ferguson and Muller (1949) indicates three periods of folding: the first, Pre-Permian, prior to the deposition of their Excelsior Formation; the second, Pre-Upper Triassic, prior to the deposition of the Luning Formation; and the third, early Jurassic, beginning with the deposition of the Dunlap Formation.

Evidence for a Pre-Permian period of folding is found in the area of the Candelaria Hill 20 miles (32 kilometers) south of Mina. Folded rocks (Ferguson and Muller, 1949, p. 8) of the Ordovician Palmetto Formation which trend northeast and are overturned to the northwest, are overlain by rocks of the Permian Diablo Formation which strike west and dip north.

Although Ferguson and Muller (1949, p. 8) propose the second period of folding as being Pre-Upper Triassic, they go on to say that if the Excelsior is found to be Permian, this folding could be dated as Pre-Middle Triassic. Much of Muller's and Ferguson's Excelsior Formation has been found to be Permian by Nielson (1964) and Talukar (1972). This changes the second period of folding to Pre-Middle Triassic. This period of folding (Ferguson and Muller, 1949, p. 8) is indicated by the marked angular unconformity between the Excelsior Formation and the overlying Luning Formation.

Ferguson and Muller (1949) and Stanley (1971) point out that the deposition of the Dunlap Formation signals the beginning of the early Jurassic orogeny, the third period of folding. The terrigenous clastic sediments contained in the Dunlap, according to Ferguson and Muller (1949), Nielson (1964) and Stanley (1971), were derived from local uplifts. Ferguson and Muller feel that backfolding and local thrusts were the result of increased intensity of folding and uplift of previously folded rocks. Large scale thrusts occurred as the deformation continued.

Two types of large high angle faults are recognized in Mineral County; one is right lateral strike slip, and the other, range front normal faults. Based on evidence collected during the study of the Cedar Mountain earthquake of 1932, Gianella and Callaghan (1934) discovered some important facts concerning the structure of the Western Great Basin. They found the earthquake had caused movement in a rift zone comprised of a number of rifts. This zone is an elongate area between the Paradise Range-Cedar Mountains on the east and the Gabbs Valley Range-Pilot Mountains on the west. Displacement in the rift zone was right lateral strike slip. They also recognized a belt of valleys that marked a change from dominantly northwesterly to dominantly north or northeasterly trending mountain ranges, which generally parallel the Nevada-California border. In 1935 Billingsley (Locke, et al., 1940) named this belt Walker Lane.

The positions of different formations and structures on both sides of Soda Spring Valley, 5 miles (8 kilometers) east of the Garfield mining district, indicate a right-lateral displacement of about 12 miles (19 kilometers) which Nielson (1965, p. 1301) associates with right-lateral strike slip faulting in the Walker Lane.

The Walker Lane, according to Albers (1967), lies along the eastern margin of a belt 50 miles (80 kilometers) wide and 300 miles (480 kilometers) long, in which the mountain ranges have an arcuate form. He suggests that the arcuate form is the result of tectonic bending. Within this belt are five major northwest-trending faults having right-lateral displacement of several miles. The bending and large scale strike slip faulting (Albers 1967) are the result of deep-seated right lateral shear system oriented northwest-southeast. He estimates total displacement along the belt at about 80 to 120 miles (120 to 190 kilometers) with the Basin and Range Province moving southward relative to the Sierra Nevada.

Basin and Range front faulting began (Silberman, 1976) about 17 million years ago. This type of faulting is still continuing as shown by a fault scarp associated with the 1954 earthquake in northern Mineral County (Ross, 1961, p. 54).

LOCAL GEOLOGY

STRATIGRAPHY

The rocks exposed in the district range in age from Triassic to Quaternary, but are dominantly Triassic and Jurassic. Tertiary and Quaternary rocks surround the district to the north, south and west, overlying the rocks that are mineralization hosts. They provide the limits of mapping. The major emphasis in this study was on the older formations and in particular the rocks Ferguson and Muller mapped as Excelsior Formation and the clastic member of the Luning Formation, because they contain the mineralization.

During the course of this study, rocks previously mapped by Ferguson and Muller (1949) as Excelsior and Luning Formations were found to be quite similar to those mapped by Nielson (1964) in the eastern Garfield Hills as Gold Range Formation (Fig. 3). Thin sections of the rocks in Ferguson's and Muller's clastic member of the Luning Formation were found to contain varying amounts of volcanic material and these rocks appear to conformably overly the rocks they mapped as Excelsior. It was concluded that rocks previously mapped as Excelsior and the clastic member of the Luning Formation are part of the Gold Range Formation.

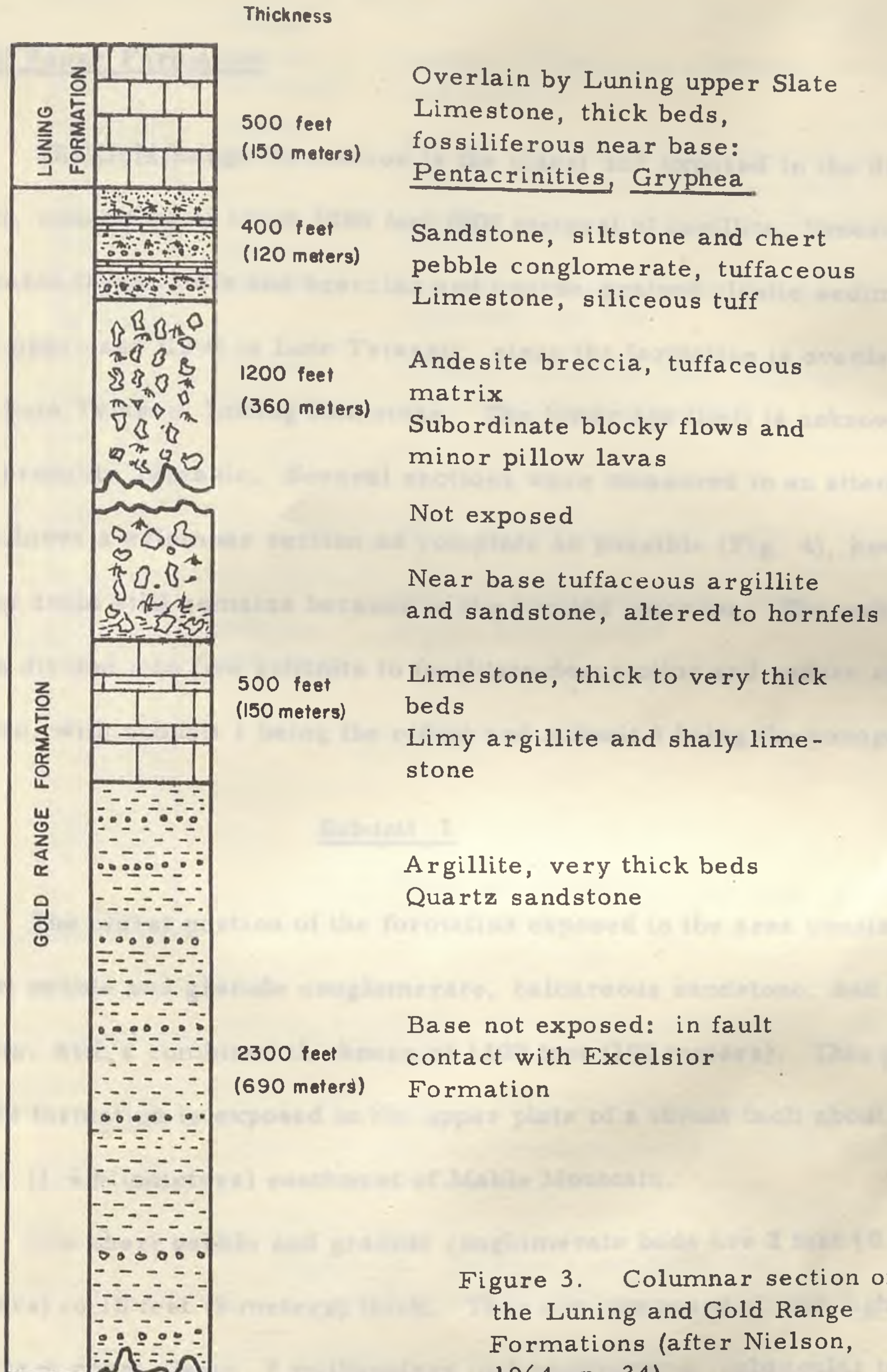

Figure 3. Columnar section of the Luning and Gold Range Formations (after Nielson, 1964, p. 34).

Triassic System

Gold Range Formation

The Gold Range Formation is the oldest unit exposed in the district, consisting of about 3000 feet (900 meters) of argillite, limestone, volcanic flows, tuffs and breccias and coarse-grained clastic sediments. The upper age limit is Late Triassic, since the formation is overlain by the Late Triassic Luning limestone. The lower age limit is unknown, but probably Triassic. Several sections were measured in an attempt to achieve a columnar section as complete as possible (Fig. 4), however, some doubt still remains because of the limited outcrops. The unit has been divided into five subunits to facilitate description and reduce confusion, with subunit 1 being the oldest and subunit 5 being the youngest.

Subunit 1

The oldest portion of the formation exposed in the area consists of chert pebble and granule conglomerate, calcareous sandstone, and argillite, with a combined thickness of 1300 feet (390 meters). This part of the formation is exposed in the upper plate of a thrust fault about 1 mile (1.6 kilometers) southwest of Mable Mountain.

The chert pebble and granule conglomerate beds are 2 feet (0.6 meters) to 10 feet (3 meters) thick. They are composed of both light and dark chert clasts, 2 millimeters to 4 centimeters, subangular to

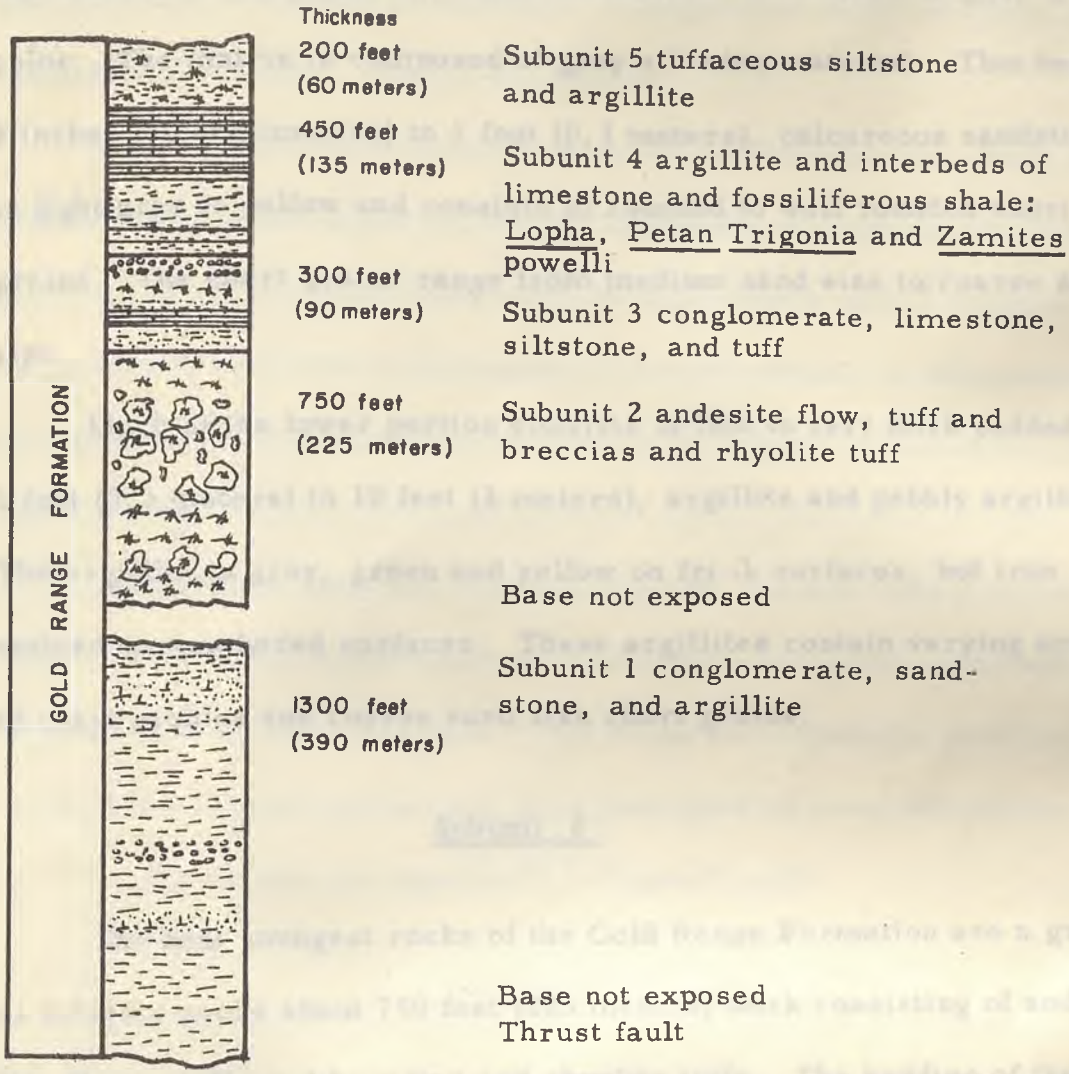

Figure 4. Columnar section of the Gold Range Formation.

subrounded and poorly sorted. Some of the light colored chert is white and exhibits a wavy pattern, while the dark chert is black to gray in color. The matrix is composed of gray silt size material. Thin bedded, 4 inches (10 centimeters) to 1 foot (0.3 meters), calcareous sandstone is light gray to yellow and consists of rounded to well rounded chert grains. The chert grains range from medium sand size to coarse sand size.

Much of the lower portion consists of thin to very thick bedded, 1 foot (0.3 meters) to 10 feet (3 meters), argillite and pebbly argillite. The argillite is gray, green and yellow on fresh surfaces, but iron stained on weathered surfaces. These argillites contain varying amounts of chert pebbles and coarse sand size chert grains.

Subunit 2

The next youngest rocks of the Gold Range Formation are a group of volcanic rocks about 750 feet (225 meters) thick consisting of andesite flows, tuffs and breccias and rhyolite tuffs. The bedding of these rocks is not well defined, but where recognized, the beds are about 5 feet (1.5 meters) thick.

The andesite flows are green on fresh surfaces and light greenish-brown on weathered surfaces. In hand specimen these rocks have a porphyritic texture with phenocrysts of tabular plagioclase, up to 4 millimeters and tabular phenocrysts of pyroxene up to 2 millimeters set in a dark green groundmass. In thin section the primary minerals are plagioclase and pyroxene in a felted groundmass of plagioclase with secondary minerals albite, chlorite, epidote and calcite.

The tuffaceous portion of the andesite tuff breccias are greenish-brown on weathered surfaces, but the fragments of andesite are light green. The clasts range from about 10 millimeters up to 3 meters, but generally are about 1 centimeter to 6 centimeters. In thin section the mineralogy of the breccias is found to be similar to that of the andesite flows.

The rhyolitic tuffs are not well exposed, but are light gray with small dark streaks on the weathered surfaces and medium gray with black streaks on fresh surfaces. The rocks are extremely hard and much of the original texture has been destroyed by recrystallization, but the dark streaks are apparently collapsed lapilli.

Subunit 3

Overlying the volcanic rocks just described are rocks consisting of tuffaceous chert-pebble conglomerate and recrystallized limestone, siltstone and air fall tuff, with a combined thickness of about 300 feet (90 meters).

The chert pebble conglomerate is black on fresh and weathered surfaces. The beds are about 5 feet (1.5 meters) thick, composed of dark gray and black chert set in a black tuffaceous matrix.

The recrystallized limestone is light brown in color on fresh and weathered surfaces and the beds are from 2 feet to 5 feet (0.6 meters to 1.5 meters) thick.

The siltstone is recrystallized to a hornfels-like rock, dark gray, white and black in color. These rocks are extremely hard and have beds which are from 4 feet to 10 feet (1.2 meters to 3 meters) thick.

The air fall tuff is medium gray on fresh surfaces and light gray on weathered surfaces. The beds are about 4 feet (1.2 meters) thick and contain concentric ring structures about 5 millimeters in diameter. These concentric ring structures appear to be accretionary lapilli which Nielson (1964, p. 51) also reported in rhyolitic rocks of the Gold Range Formation.

Subunit 4

The next youngest rocks consist of argillite and interbeds of limestone and shale, with a combined thickness of 450 feet (135 meters).

The argillite is light brown on fresh and weathered surfaces, but somewhat redder on weathered surfaces. The unit is not well exposed but appears to have beds which are about 5 feet to 10 feet (1.5 meters to 3 meters) thick.

The individual beds that make up the interbedded limestone and shale range from 2 feet (0.6 meters) to 10 feet (3 meters) in thickness. The limestone is medium gray to dark gray on fresh surfaces and medium gray or occasionally iron stained on weathered surfaces. A few of the beds exhibit differential weathering, as these contain lenses of black siltstone. The limestone is nonfossiliferous, but the shale is highly fossiliferous. Both plant and animal fossils were found in these shale beds, which contain abundant invertebrate fossils and sparse plant fossils. The invertebrate fossils are molluscs, chiefly pelecypods and a few gastropods and cephalpods. Some of the pelecypods have tentatively been identified as Lopha, Petan, and Trigonia (Cornwall, personal communication). Plant fossils from the shale beds consist of leaf imprints which were identified as Zamites powelli (Ash, personal communication).

Subunit 5

Rocks of this subunit overlie subunit 4 and are conformably overlain by the upper limestone of the Luning Formation. Rocks in subunit 5 consist of tuffaceous siltstone and argillite with a combined thickness of about 200 feet (60 meters).

The tuffaceous siltstone and argillite range in color from gray to black on fresh surfaces, with the darker siltstone iron stained on weathered surfaces. Occasionally small flakes of biotite, up to 1 millimeter, are visible, but this is the only recognizable mineral in hand specimen. In thin section these rocks are seen to be composed of broken crystals of quartz and plagioclase, biotite, lithic fragments, collapsed lapilli and devitrified glass shards. The beds range in thickness from

3 feet (1 meter) to 10 feet (3 meters).

Nielson (1964) has interpreted the andesite flows and breccias as being submarine and deposited close to the volcanic vents. The rhyolitic tuffs he interprets as air fall tuffs and the clastic sediments as being deposited in shallow water. This study found no evidence to support or disprove Nielson's interpretation of the andesite flows and breccias. The presence of accretionary lapilli, according to Moore and Peck (1962, p. 191), suggests air fall tuff probably within 10 miles (16 kilometers) of the source vent. They also indicate deposition on land or shallow water. The plant fossils indicate a near shore environment of deposition. The pelecypods in the shale also suggest a shallow environment.

Luning Formation

The Luning Formation as applied here consists of only the Upper Limestone and Upper Slate units recognized by Ferguson and Muller (1949, p. 5) with a total thickness of about 1100 feet (330 meters). This usage is consistent with that of Nielson (1964). The rocks are Late Triassic in age.

The limestone within the mapped area is thick to very thick bedded, about 2 feet (0.6 meters) to 8 feet (2.4 meters) thick, dark gray, with sharp irregular protrusions on weathered surfaces. Minor amounts of thin bedded shaly limestone, light gray, with irregular parting occur primarily near the base, with lesser amounts elsewhere. The limestone exhibits recrystallized white calcite stringers which are parallel or subparallel to bedding and less than 5 millimeters in width. The limestone generally appears to be nonfossiliferous, but a few beds, 1 foot (0.3 meter) to 3 feet (1 meter) thick of bioclastic limestone were observed. The only fossil fragments recognizable were those of pelecypods which are dark gray to black set in a medium gray calcareous matrix. Occurring within the limestone is a slate unit which according to Ferguson and Muller (1949, p. 5) only reaches mappable thickness in the Garfield Hills. This unit is of sufficient thickness to be mapped in the northernmost part of the area (Plate 1). The unit is about 130 feet (39 meters) thick, consisting of chert pebble conglomerate, argillite and limestone. Near the base is a maroon siltstone which Nielson (1964, p. 35) reports is a marker unit in the north central Pilot Mountains and Garfield Hills. The estimated combined thickness of the limestone and slate unit is 1100 feet (330 meters). This figure seems reasonable, since Nielson (1964, p. 34) measures a combined thickness of 1120 feet (336 meters) between Mina and Luning, T6N, R34E, in the eastern Garfield Hills.

The pelecypod fragments in the bioclastic limestone suggest a shallow water environment. The similarity between the chert in the conglomerate of the Luning Formation and the chert of the Excelsior Formation, suggests that at least part of the Luning slate unit was derived from the Excelsior Formation.

Jurassic System

Dunlap Formation

The Lower Jurassic Dunlap Formation consists of four members. From bottom to top they are as follows: sandstone, limestone, andesite, and conglomerate. The Dunlap Formation overlies the Luning and Gold Range Formations with an angular discordance of about 20 degrees. Muller and Ferguson (1939, p. 1619) estimate the maximum thickness to be about 3000 feet (900 meters) here. Work by Muller and Ferguson (1936), Nielson (1964) and Stanley (1971) show that while the Dunlap Formation was deposited over a large area, it was restricted to structural troughs. One of these troughs occurs in the southeastern portion of the area (Plate 1). It is about 1 mile (1.6 kilometers) wide and 4 miles (6.4 kilometers) long and has an axial trend of northeast. Muller and Ferguson (1939) and Stanley (1971) mention that the lithologic character is highly variable and beds on one side of the trough can not be matched to the opposite side. Stanley (1971) worked in a portion of this same trough about 2 miles (3 kilometers) to the northeast of the Bluelight mine. The columnar section he derived for the area is presented in Figure 5.

The sandstone member which consists of intercalated quartz sandstone and siltstone is estimated to be about 1200 feet (360 meters) thick. The sandstone is thin to thick bedded and red in color. The siltstone is

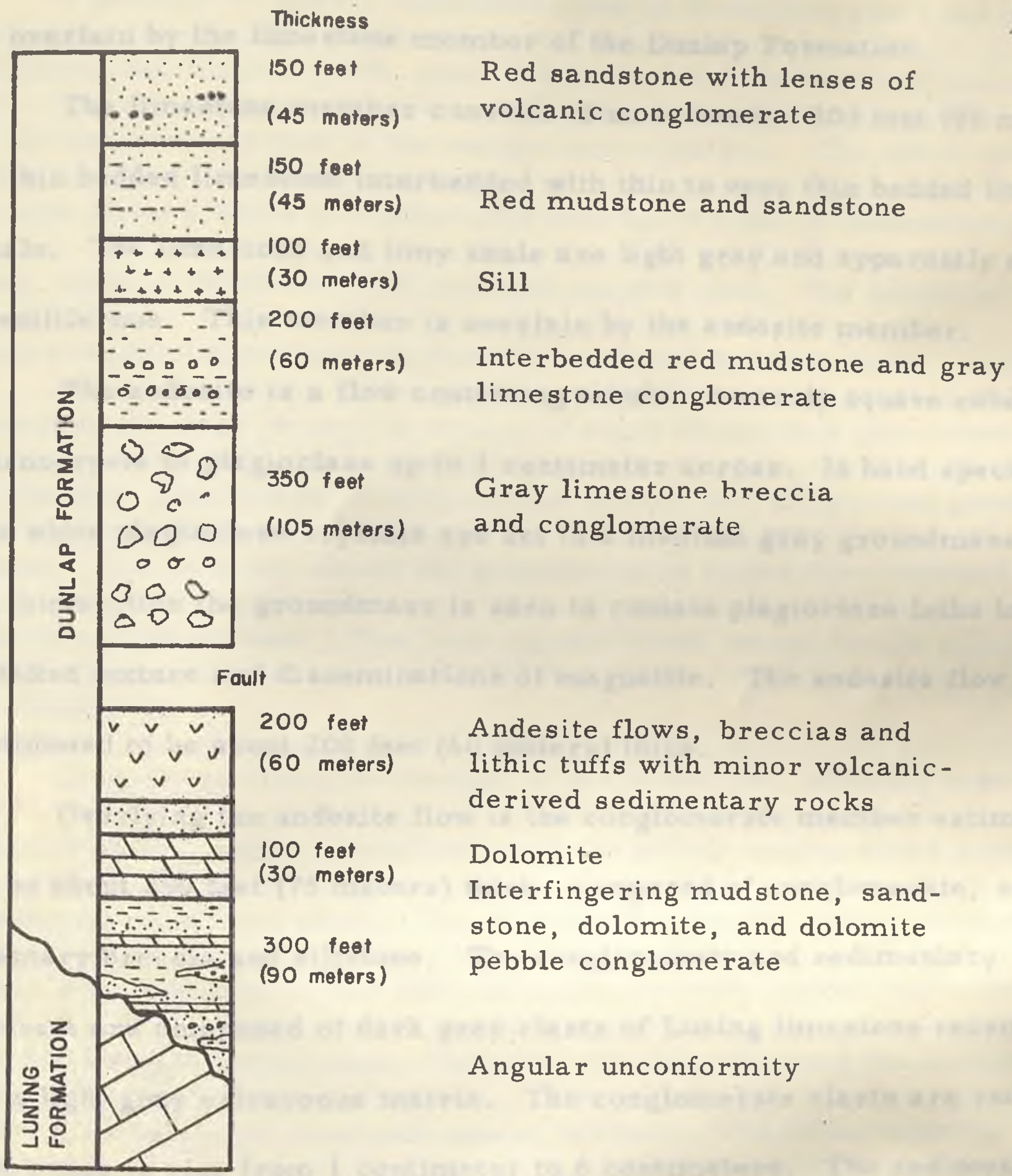

Figure 5. Columnar section of the Dunlap Formation (after Stanley, 1971, p. 462).

very thin bedded, black, maroon and light green in color. This member unconformably overlies the Luning and Gold Range Formations and is overlain by the limestone member of the Dunlap Formation.

The limestone member consists of an estimated 300 feet (90 meters) of thin bedded limestone interbedded with thin to very thin bedded limy shale. The limestone and limy shale are light gray and apparently nonfossiliferous. This member is overlain by the andesite member.

The andesite is a flow containing tabular to nearly square euhedral phenocrysts of plagioclase up to 1 centimeter across. In hand specimen the white plagioclase crystals are set in a medium gray groundmass. In thin section the groundmass is seen to contain plagioclase laths having a felted texture and disseminations of magnetite. The andesite flow is estimated to be about 200 feet (60 meters) thick.

Overlying the andesite flow is the conglomerate member estimated to be about 250 feet (75 meters) thick, composed of conglomerate, sedimentary breccia and siltstone. The conglomerate and sedimentary breccia are composed of dark gray clasts of Luning limestone recemented by a light gray calcareous matrix. The conglomerate clasts are rounded and range in size from 1 centimeter to 6 centimeters. The sedimentary breccia clasts are very angular and range in size from 1 centimeter to 20 centimeters. The siltstones are very thin bedded and are maroon, black and light gray in color.

Cretaceous Igneous Rocks

A porphyritic quartz monzonite dated at 84 million years old by Evernden and Kistler (1970, plate 2) has intruded the Dunlap Formation in the southeastern part of the mapped area (plate 1). The stock covers an area about 2 miles (3 kilometers) wide and 4 miles (6 kilometers) long, most of which does not lie in the mapped area. The outcrops have a rounded appearance typical of weathered granitic rocks. In hand specimen the rock is seen to consist of about 40 per cent phenocrysts of orthoclase, plagioclase, biotite and hornblende and 60 per cent groundmass. Thin sections reveal the groundmass is primarily composed of quartz and plagioclase. The rock appears fresh except for the effects of weathering.

Granophyre dikes are thought to be Cretaceous, probably associated with late stage crystallization of the parent magma which produced the quartz monzonite stock. The only age that can be applied to these dikes with certainty is post Late Triassic, for they intrude the Luning and Gold Range Formations. They intrude along fissures which have a north or northeast trend and appear vertical. The dikes range in width from about 10 feet (3 meters) to 200 feet (60 meters) and can be traced on the surface for up to 1000 feet (300 meters). They are highly fractured, forming extremely hard, very light tan angular blocks. The weathered surfaces are somewhat darker, being stained with limonite and manganese oxides. No minerals in the hand specimen were recognizable, but in thin section plagioclase and orthoclase, up to 0.3 millimeters in diameter, are seen to be enclosed by micro-graphic intergrowths of orthoclase and quartz. The orthoclase crystals are being replaced by sericite while the plagioclase is being altered to albite and secondary orthoclase.

Tertiary System

Rocks of this period are dominantly volcanic with a minor sedimentary unit. The volcanic rocks are of three compositions: rhyolite tuff, intermediate tuffs and flows and a basaltic flow.

The oldest of the Tertiary units is a highly friable dark brown sandstone, estimated to be about 30 feet (9 meters) thick; the base, however, is not exposed. This unit only crops out in a few locations and is overlain by a rhyolite tuff. The outcrops of the sandstone are too small to be mapped at the scale used for plate 1.

The rhyolite tuff which overlies the sandstone crops out in five mappable locations (plate 1). In hand specimen the rock is seen to be light gray, with conspicuous biotite flakes and quartz phenocrysts, and pumice lapilli. The unit is about 60 feet (18 meters) thick.

Overlying the rhyolite tuff is the Gilbert andesite, an intermediate composition volcanic unit. It consists chiefly of rhyodacite to andesite flows, tuffs and breccias (Ross, 1961). This unit is quite extensive and appears to contain several of the varieties of rocks mentioned. The unit is estimated to exceed 100 feet (30 meters) in thickness.

A basalt flow dated at 8.5 million years old by Silberman et al., (1975, p. 17) covers a large area to the north and west of the mapped area. In hand specimen the rock appears black, vesicular, with visible olivine on fresh surfaces. This unit is estimated to exceed 20 feet (6 meters) in thickness.

Quaternary System

The Quaternary deposits are alluvium, consisting of gravels, slope wash and valley fill. Garfield Flat, about 8 miles (13 kilometers) south of the mapped area, is a playa receiving fine-grained sediments and was possibly a small enclosed lake during the Pleistocene.

STRUCTURE

The structure of the district is quite complex, having undergone folding, uplift and thrust faulting during an Early Jurassic orogeny as discussed in the regional structure section. The complexity was further increased by high angle faulting during post-Jurassic times.

The Early Jurassic orogeny appears to have been responsible for the folding and thrust faulting within the area (plate 1). Throughout much of the district the axial traces of folds trend northeast and the axial planes dip to the southeast (plate 1, cross section A-A'). The folds are overturned to the northwest, with the broader folds being more symmetrical and the tighter ones being more isoclinal. According to

Ferguson and Muller (1949, p. 19) this fold pattern is presumably due to deflection of later folds by earlier folded and uplifted rocks.

There appear to be thrust faults with both small and large displacement. The thrust faults with the smaller displacements are associated with rupture in tight folds (Plate 1, cross section A-A' and B-B'). This type is difficult to detect and it seems possible that a number of these faults may exist and have gone undetected. The thrust faults having larger displacements appear to have moved about a mile, with the possible exception of the thrust plate containing the coarse clastic rocks of the Gold Range Formation (Plate 1, cross section B-B'). The thrust faults having the mile displacements appear to contain continuations of the folded rocks from the east side of Mable Mountain which have wrapped around the southwest flank of Mable Mountain by thrust faulting.

Most of the high angle faults are normal faults with apparently small horizontal and vertical displacements. The longer faults, recognized on aerial photographs, when field checked were found to dip within 20 degrees of the vertical. Most of the faults did not, however, have exposures on which the dip could be determined. When the strikes of the faults recognized on aerial photographs are plotted on a rose diagram (Fig. 6), four dominant groups are revealed: N10°-20°W; N35°-40°W; N45°-50°W and N75°-80°W. The faults which have a strike between N10°-20°W are in the vicinity of the quartz monzonite stock (plate 1) and are thought to be associated with the uplift caused by the stock as

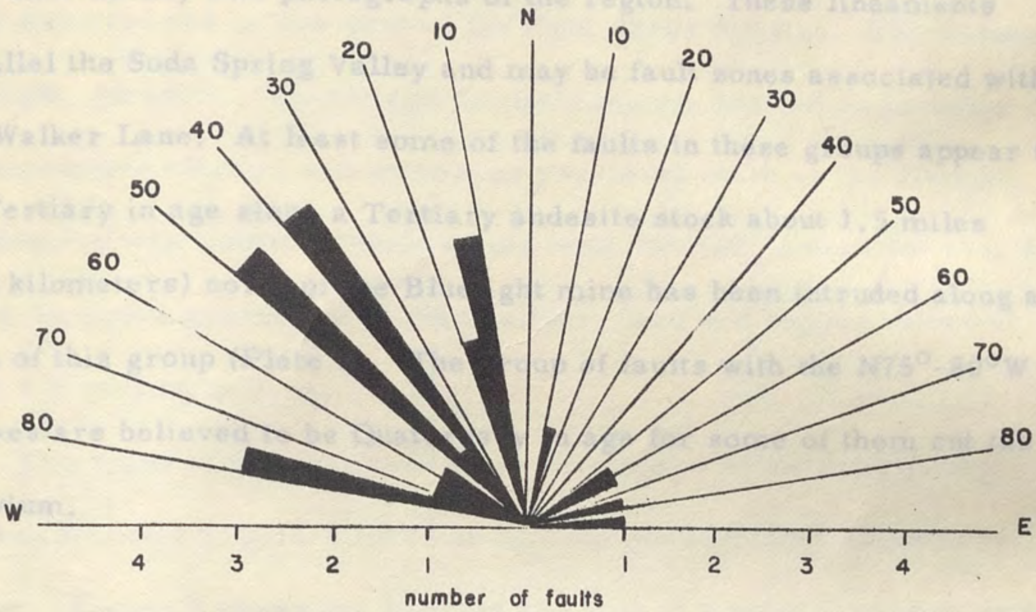

Figure 6. The frequency of strikes, surface faults in the Garfield mining district.

it intruded the overlying rocks. If these faults were caused by the uplift on the stock, then since the stock is Cretaceous the faults are also Cretaceous in age. The two most prominent groups of faults, N35°-40°W and N45°-50°W, are parallel to a set of lineaments which can be seen on high altitude Sky Lab photographs of the region. These lineaments parallel the Soda Spring Valley and may be fault zones associated with the Walker Lane. At least some of the faults in these groups appear to be Tertiary in age since a Tertiary andesite stock about 1.5 miles (2.4 kilometers) north of the Bluelight mine has been intruded along a fault of this group (Plate 1). The group of faults with the N75°-80°W strikes are believed to be Quaternary in age for some of them cut the alluvium.

ECONOMIC GEOLOGY

The Garfield district occupies sections 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, and 28 of T7N, R33E; however, in recent usage the district has been combined with several other districts and is now part of the Gold Range district. The Bataan, Bluelight, Mendora, Mabel, and Garfield mines, located on patented and unpatented claims, and numerous prospects make up the district. The district was intermittently active from the 1880's until the 1940's with a recorded production of gold, silver, lead and copper valued at about 1.5 million dollars.

Two types of mineralization are recognized in the district; epithermal deposits of gold-silver and igneous metamorphic deposits of copper. Figure 7 shows the location and type of mineralization of mines and prospects on a reduced and simplified geologic map of the district. The mineralization occurs in Mesozoic rocks of the Luning, Gold Range and Dunlap formations with alteration extending some distance beyond known mineralization. There is no known mineralization in the Tertiary rocks in or around the district. Figure 8 shows the locations and types of alteration.

The following discussions will describe the mines in the district, summarize their characteristics, estimate the ore potential of each mine and suggest possible sites for exploration.

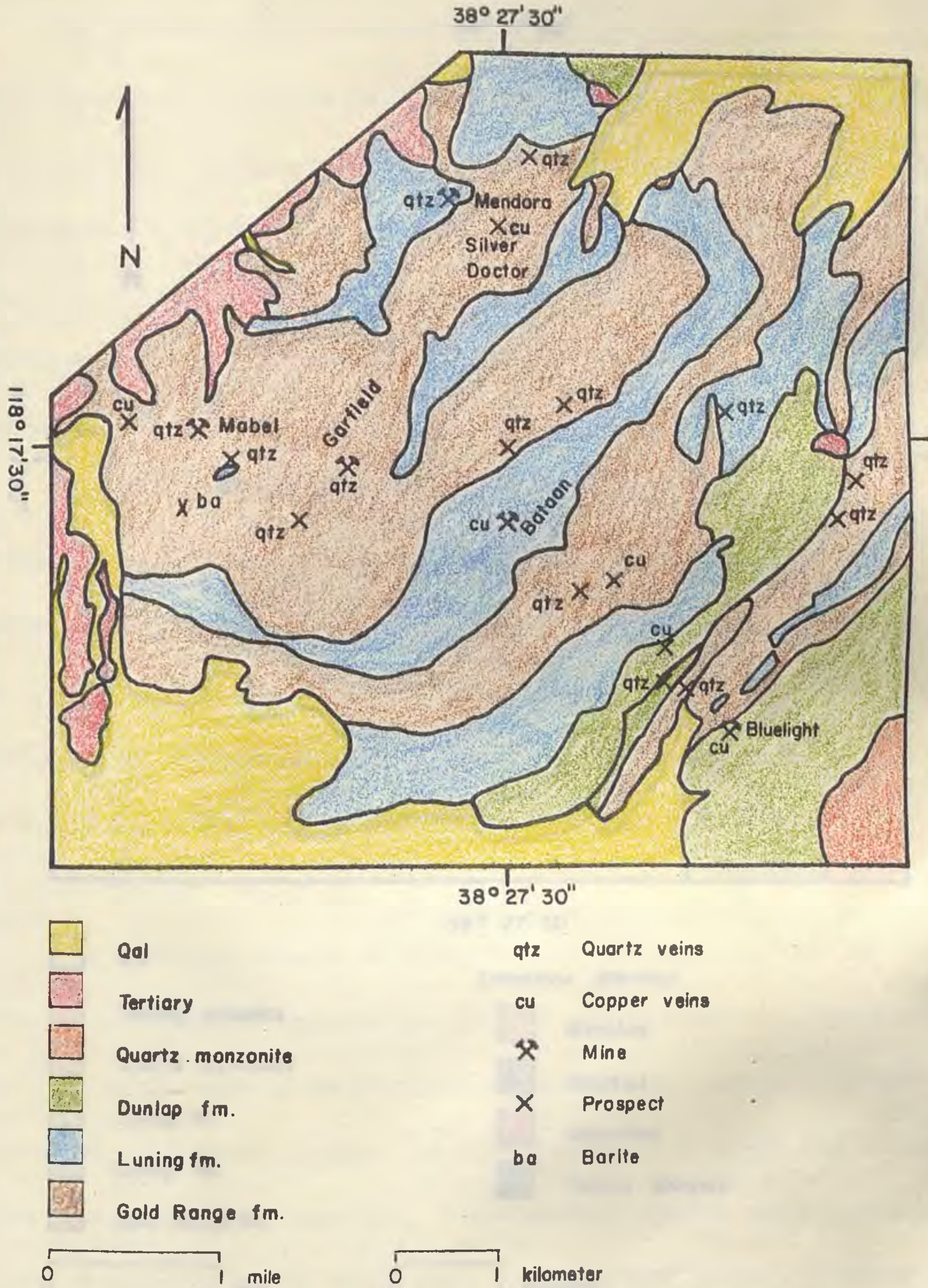

Figure 7. Location of mines and prospects in the Garfield mining district.

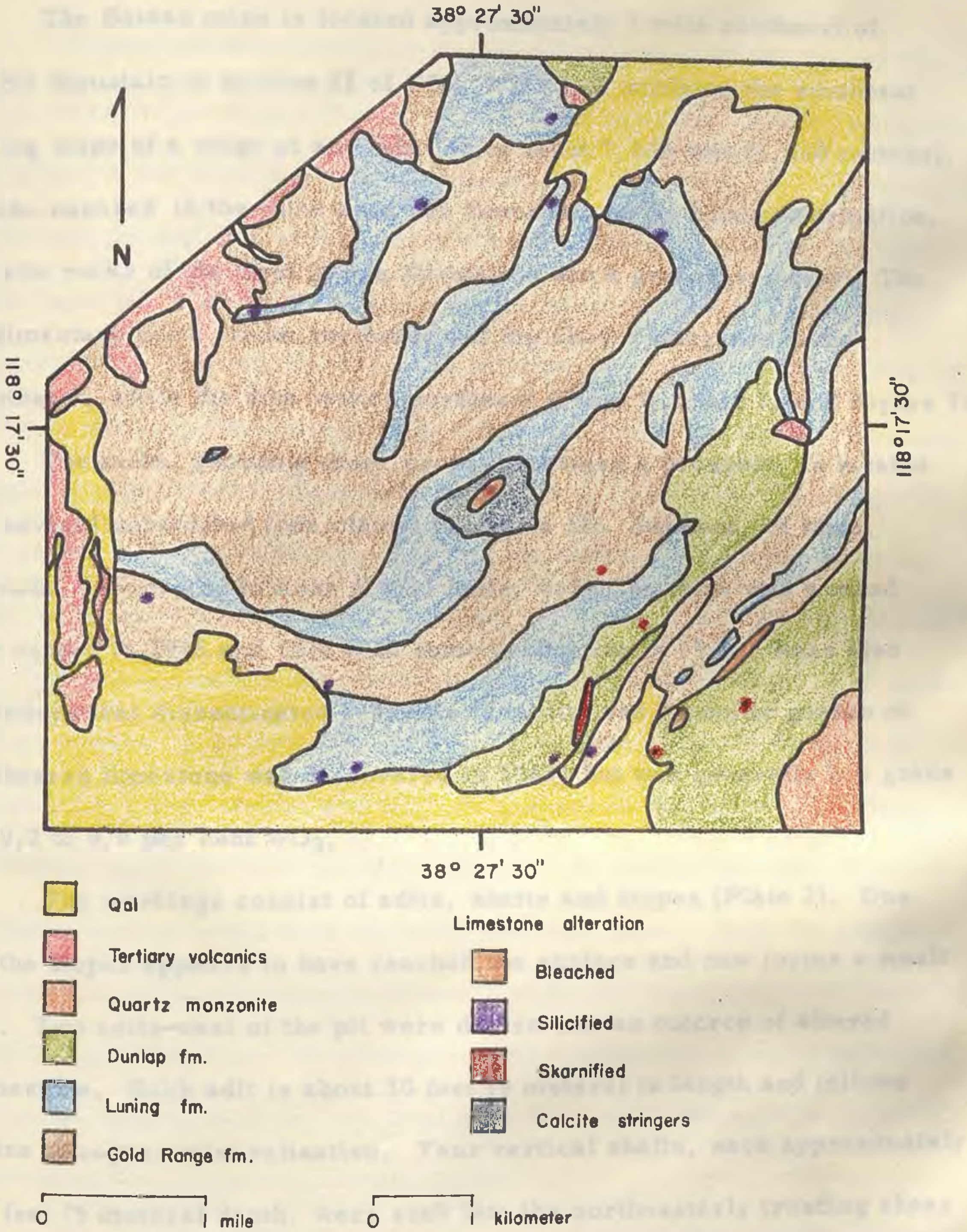

Figure 8. Limestone alteration in the Garfield mining district.

BATAAN MINE

The Bataan mine is located approximately 1 mile southeast of Mable Mountain in section 22 of T7N, R33E. It occupies the southeast facing slope of a ridge at an elevation of about 7, 500 feet (2, 250 meters). Rocks exposed in the mine area are limestone of the Luning Formation, clastic rocks of the Gold Range Formation and a granophyre dike. The sedimentary units strike northeast and dip about 50 degrees to the southeast, while the dike trends northeast (Plate 1, Plate 2, and Figure 7).

The mine, probably more properly termed a prospect, is located on several unpatented lode claims held by a Mr. Swanson, of Mina, Nevada. According to Ross (1961, table, 6.3), the mine was worked for copper in 1915 and 1916 with some production in 1916. Ross also mentions that disseminated scheelite in tactite and limonitic gossan of a sheared limestone was discovered in 1943, but was generally low grade at 0.2 to 0.8 per cent WO_3.

The workings consist of adits, shafts and stopes (Plate 2). One of the stopes appears to have reached the surface and now forms a small pit. Two adits west of the pit were driven into an outcrop of altered limestone. Each adit is about 30 feet (9 meters) in length and follows veins of copper mineralization. Four vertical shafts, each approximately 30 feet (9 meters) depth, were sunk into the northeasterly trending shear zone. The caved stope forms a pit 20 feet (6 meters) deep and 75 feet (23 meters) in diameter. There are remnants of an adit which pass beneath the road and into the pit from the east. Apparently the adit once continued through what is now the pit.

Copper mineralization occurs in the limestone of the Luning Formation in six veins up to 6 inches (15 centimeters) wide. The mineralization appears to be limited to a northeasterly trending shear zone approximately 200 feet (60 meters) wide about 300 feet (90 meters) south of the dike and parallel to it. The minerals in the vein are azurite, malachite, brochanite, chrysocolla, tenorite, calcite, garnet and limonite (Fig. 9). Due to post ore fractures and the porous nature of the limestone, supergene copper minerals have been deposited in and around the site of the hypogene vein. The veins cross cut the bedding, trend northeast and dip between 80°SE and 80°NW. A vein specimen collected from the adit in western face of the pit was assayed by atomic absorption. The assay ran: copper, 2.20 percent; lead, 0.02 percent; zinc, 0.60 percent; and silver, 0.44 ounces per ton. Fire assay of this same specimen showed: gold, 0 ounce per ton; silver, 0.42 ounces per ton. It is not known what minerals hold the lead, zinc and silver. Only the copper minerals previously mentioned are in sufficient quantities to be detected by X-ray diffraction. Occurrence of these elements in other parts of the district suggest that the hypogene minerals were chalcopyrite, argentiferous galena, argentite and sphalerite.

The limestone, clastic rocks and granophye dikes exhibit different types of alteration. The alteration of the limestone may be divided into

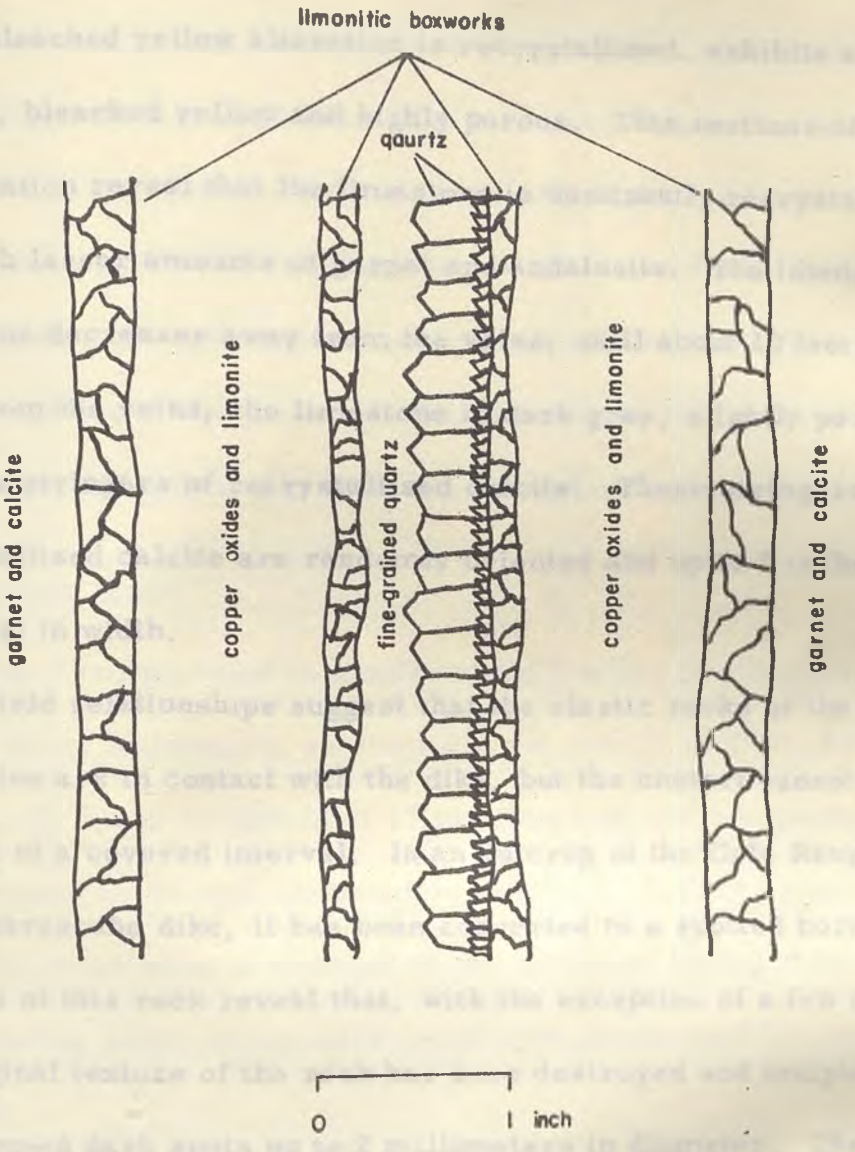

Figure 9. Cross section of a copper vein, Bataan mine.

two types based on megascopic examination: bleached yellow and recrystallized white calcite stringers. The former type may be further differentiated by microscopic examination. In hand specimen the limestone of the bleached yellow alteration is recrystallized, exhibits a sandy texture, bleached yellow and highly porous. Thin sections of this type of alteration reveal that the limestone is dominantly recrystallized calcite with lesser amounts of garnet and andalusite. The intensity of the alteration decreases away from the veins, until about 10 feet (3 meters) away from the veins, the limestone is dark gray, slightly porous and contains stringers of recrystallized calcite. These stringers of white recrystallized calcite are randomly oriented and up to 2 inches (5 centimeters) in width.

Field relationships suggest that the clastic rocks of the Gold Range Formation are in contact with the dike, but the contact cannot be seen, because of a covered interval. In an outcrop of the Gold Range Formation, nearest the dike, it has been converted to a spotted hornfels. Thin sections of this rock reveal that, with the exception of a few quartz grains, the original texture of the rock has been destroyed and incipient minerals have formed dark spots up to 2 millimeters in diameter. The minerals forming the dark spots and groundmass are too fine-grained to be identified in thin section. Graphite, iron oxide or chlorite are common minerals which form dark spots (Jackson, 1970, p. 430) in hornfels.

The dike crops out approximately 340 feet (100 meters) north of the pit and is about 1100 feet (330 meters) long and 230 feet (69 meters) wide. It is very light tan, extremely fine-grained, very hard with a blocky fracture. Thin sections show the primary minerals to be orthoclase, plagioclase and quartz. The orthoclase occurs as euhedral, tabular crystals up to 0.3 millimeters in diameter and as graphic intergrowths with quartz. The plagioclase occurs as embayed crystals up to 0.1 millimeter in diameter, partially replaced by albite and secondary orthoclase. The primary orthoclase is partly replaced by sericite and the sericite appears to have totally replaced some biotite.

BLUELIGHT MINE

The Bluelight mine is located about 3 miles (5 kilometers) southeast of Mable Mountain in sections 25, 26, and 27 of T7N, R33E (Plate 1 and Fig. 7). It is composed of 17 patented lode claims (patent survey #4123) owned by Summa Corporation and A. J. Bryant Company Diversified. The mine area is situated on the southeast facing slope of a northeast trending ridge, at an elevation of approximately 7100 feet (2130 meters).

Rocks exposed in the vicinity are the limestone, andesite and conglomerate members of the Dunlap Formation and a Cretaceous stock. This stock is a porphyritic quartz monzonite which has been dated by Everden and Kistler (1970, plate 2) at 84 million years old. The stock crops out over an area approximately 4 miles (6 kilometers) long and

2 miles (3 kilometers) wide; however, only a small portion of it occurs within the mapped area. It has intruded the Dunlap Formation and crops out about 3500 feet (1000 meters) southeast of the mine. The rocks of the Dunlap Formation strike northeast and dip about 60 degrees to the southeast, near the mine.

The Mineral Resources of the United States (1905, p. 268) states that the ". . . Bluelight mine was the largest copper producer in the county. . ." during that year. In 1908 the same publication mentions that the mine made a trial shipment of precious metal-bearing copper ore. According to Weed (1922, p. 1149), the Bluelight mine shipped several carloads of rich carbonate ore, but became inactive sometime between 1917 and 1919.

The workings consist of a 600 foot (180 meters) shaft with levels at 50 feet (15 meters), 74 feet (22.2 meters), 100 feet (30 meters) and 300 feet (90 meters) (Plate 3). The true lateral extent of the original underground development is unknown, since the map indicates that parts of the mine are caved or backfilled. The workings which are preserved total about 1500 feet (450 meters), but were not entered by the author because of safety considerations. Specimens used to determine ore and gangue mineralogy, and alteration types, were obtained from the dump or outcrop adjacent to the mine.

Copper mineralization occurs as veins in the limestone member of the Dunlap formation. The map of the underground workings indicates that mineralization is localized in a northeast trending shear zone which dips about 70 degrees to the northwest and is about 1000 feet (300 meters) long and 250 feet (75 meters) wide. Copper-bearing veins at the surface exposed in 5 bulldozer cuts range in width from 0.5 inches (13 millimeters) to 18 inches (46 centimeters), but most are less than 2 inches (5 centimeters). Some pieces of vein material found on the dump were about 2 feet (0.6 meters) wide, suggesting that some of the veins were at least 2 feet (0.6 meters) wide in the mine. Copper minerals found on the dump and in surface veins include azurite, malachite, brochanite, chrysocolla and tenorite. Two specimens in the Mackay School of Mines Museum contain chrysocolla and melaconite. The gangue minerals are limonite and calcite. The texture of the original vein has been destroyed by oxidation but the hypogene mineralization seems to have replaced the limestone along fissure openings. Mr. Saunders, geologist for Summa Corporation, mentioned (personal communication) that the ore was oxidized on all levels, no mineralization was present below the 300 foot (100 meter) level and that the shaft was boarded over at the 300 foot (100 meter) level. Two specimens in the Mackay School of Mines Museum, one of chrysocolla, the other melaconite, contain 21 percent and 19 percent copper respectively. One specimen collected from the dump and assayed by atomic absorption contained: copper, 1.23 percent: lead, 0.01 percent; zinc, 0.01 percent; and silver, 1.89 ounces per ton. This same specimen was also assayed by fire and found to contain:

gold, zero; silver, 3.60 ounces per ton. Two specimens collected from veins at the surfaces and assayed by atomic absorption were found to contain: (1) copper, 0.17 percent; lead, 0.00 percent; zinc, 0.02 percent; and silver, 6.09 ounces per ton, (2) copper, 1.33 percent; lead, 0.07 percent; zinc, 0.00 percent; and silver, 2.21 ounces per ton.

The limestone, andesite and sandstone members of the Dunlap Formation show the effects of alteration. The alteration of the limestone appears similar to that found at the Bataan mine. Specimens collected from the surface near the mine and from the dump are recrystallized, bleached light yellow, highly porous and have a sandy texture. In hand specimen this limestone appears similar to that found at the Bataan mine; however no garnet or andalusite were found in it at the Bluelight mine. Two areas of skarn occur in the vicinity of the mine (Fig. 8).

The andesite occurs in the mine vicinity and within 1000 feet (300 meters) of the intrusive and exhibits a different type of alteration at each location. Near the mineralized area, thin sections reveal that the felted groundmass of plagioclase has been replaced by secondary orthoclase, biotite, and sericite. The plagioclase phenocrysts have been replaced by secondary orthoclase, and sericite. The magnetite prevalent in the unaltered andesite is greatly reduced. An outcrop of andesite about 1000 feet (300 meters) north of the intrusive exhibits a different type of alteration. In thin section it can be seen that the plagioclase phenocrysts are partially replaced by sericite. Epidote (?) has replaced part of the groundmass and is rimmed by magnetite. Small garnets are also present up to 0.5 millimeter across.

The sandstone member of the Dunlap Formation near the intrusive is mostly siltstone, which has been converted to a hornfels. A few of the limy beds in this member have been converted to a skarn of garnet, diopside and calcite.

No copper mineralization was found in the quartz monzonite stock or in the sedimentary rocks adjacent to it. Also, the stock showed no signs of hydrothermal alteration.

MENDORA MINE

The Mendora mine is located in sections 3 and 10 of T7N, R33E about 1.5 miles (2.4 kilometers) northeast of Mable Mountain (Plate 1 and Fig. 7). It is situated on several unpatented lode claims, held by a Mr. Parker of Mina, Nevada. The mine area occupies the northwest facing slope of a northeasterly trending ridge at an elevation of 6,700 feet (2010 meters).

Rocks exposed in the vicinity are clastic and volcanic rocks of the Gold Range Formation, limestone of the Luning Formation, and granophyre dikes. The rocks strike northeast and dip about 50 degrees to the northwest.

Assay sheets from the American Smelting and Refining Company indicate that gold-silver ore was mined in 1938 and 1939 at the Mendora mine. These sheets also show that 10 lots were shipped, but figures for lot one no longer exist. A total of about 194 tons were shipped having an average assay of: copper, 0.99 percent; lead, 2.62 percent zinc, 0.02 percent; silver, 42.08 ounces per ton; and gold, 0.399 ounces per ton.

The workings consist of a 100 foot (30 meters) vertical shaft with levels at 50 feet (15 meters) and 100 feet (30 meters), and several adits. The extent of lateral workings on the two levels of the shaft is about 2100 feet (700 meters). The shaft was sunk into an altered outcrop of Luning limestone and is generally in good repair, but many of the adits driven into rocks of the Gold Range Formation are caved. According to Bishop (1968) the several adits have a total of about 3000 feet (1000 meters) of cross cuts and drifts.

Mineralization on the 100 foot (30 meter) level in the shaft occurs in two quartz veins which trend northeast and dip between 72 degrees southeast and 73 degrees northwest (Plate 4). Drifts expose both veins, one for a length of 60 feet (18 meters) and the other for a length of 43 feet (13 meters). The veins range between 2 feet (0.6 meters) and 4 feet (1.2 meters) and average about 2.5 feet (0.75 meters) in width. The vein fillings consist of iron stained quartz, limonite, cerussite, jamesonite, pyrite, stibnite and pyrargrite. The jamesonite, cerussite, pyrite and limonite occur in spaces between coarse crystalline quartz and as fine particles in fine-grained quartz. The stibnite, pyrargrite, pyrite and limonite occur near the vein wall in silicified and iron stained limestone.

In places post ore movement has crushed the vein and apparently good values were found in these areas as reflected by the stoping. A specimen of the crushed quartz was analyzed by X-ray diffraction and found to contain jamesonite, cerussite, calcite and quartz. One vein of coarse crystalline brown calcite 1 foot (30 centimeters) to 2 feet (60 centimeters) wide, parallels the quartz vein. A specimen of the quartz vein (plate 4) was assayed by atomic absorption and found to contain: copper, 0.02 percent; lead, 0.23 percent; zinc, 0.18 percent; and silver, 1.49 ounces per ton. Fire assay of the same specimen showed: gold, a trace; silver, 1.44 ounces per ton. A specimen collected from the dump and assayed by atomic absorption contained: copper, 0.03 percent; lead, 0.03 percent; zinc, 0.04 percent; and silver, 2.68 ounces per ton.

The limestone near the vein is silicified, highly porous and heavily iron stained. About 8 feet (2.4 meters) away from the vein the limestone is bleached light yellow and consists dominantly of fine-grained recrystallized calcite, with veins of coarse-grained recrystallized calcite up to 4 millimeters wide and pseudomorphs of limonite up to 1 centimeter across. Argillite of the Gold Range Formation occurs about 200 feet (60 meters) away from the nearest vein and it is unaltered.

Adits were driven into the northeast slope of the ridge until the vein or veins were interested. At that point, drifts were driven along the vein. The quartz veins reached by the adits are similar to the veins at the shaft. Judging by the number of adits, their location, and the quartz vein material on the dumps, it appears that the vein or veins are at least semi-continuous for about 1400 feet (420 meters). The positions of the adits also suggest that the vein system has been explored vertically about 200 feet (60 meters).

A specimen collected from a dump about 1100 feet (330 meters) east of the shaft was assayed by atomic absorption and found to contain: copper, 0.90 percent; lead, 1.14 percent; zinc, 0.54; and silver, 16.33 ounces per ton. Fire assay of this same specimen showed: gold, 0.044 ounces per ton; silver, 19.93 ounces per ton.

Two specimens of the Gold Range Formation collected from the adit about 1130 feet (340 meters) east of the shaft show different types of alteration. The first specimen, collected 43 feet (13 meters), from the portal is slightly altered. A thin section reveals that the groundmass is being replaced by secondary biotite and sericite and the plagioclase phenocrysts are just beginning to be replaced by sericite. The second specimen, probably originally an argillaceous rock, was collected 620 feet (186 meters) from the portal. This specimen is altered to a spotted hornfels. Had this adit continued 300 feet (100 meters) farther, it would have passed through the ridge and come out near a copper prospect known as the Silver Doctor, which is in a hornfelsic rock of the Gold Range Formation. Mineralization there consists of copper in quartz veins up to 2 centimeters in width. The copper minerals are chrysocolla, malachite and tenorite. A specimen collected from the dump at the Silver Doctor prospect was assayed by atomic absorption and found to contain: copper, 1.28 percent; lead, 0.12 percent;

zinc, 0.39 percent; and silver, 1.49 ounces per ton. Fire assay of this specimen showed: gold, trace; silver, 1.64 ounces per ton. This copper mineralization occurs about 30 feet (9 meters) from a grandophyre dike.

MABEL MINE

The Mabel mine is located about 0.75 mile (1.2 kilometers) northwest of Mable Mountain, in sections 17, 18, 20, and 21 of T7N, R33E (Plate 1 and Fig. 7). It is covered by one of several unpatented lode claims held by Summa Corporation and is situated at an elevation of about 7,100 feet (2,130 meters). Rocks of the Gold Range Formation are exposed in the vicinity of the mine. The strike and dip of these units are quite varied, but in general they strike northeast and dip southeast.

Couch and Carpenter (1943, p. 105) show production by the West End Consolidated Mining Company, former owners of the Mabel mine, from 1922 to 1940 to be 9,632 tons valued at $745,471. According to Ferguson, Muller and Cathcart (1954) quartz veins broken by post-mineral faults contain argentite and argentiferous galena at depth and cerargyrite and native silver near the surface.

The workings consist of several adits caved at the portals and a 600 foot (180 meter) shaft with levels approximately every 100 feet (30 meters). To reduce confusion the workings are shown on two plates. All the workings for the Mabel mine and Lancashire claim, without geology, appear on plate 6. Plate 7, on the other hand, shows the workings for only the Lancashire #1 adit and the 100, 300, and 500 levels of the Mabel mine, all with the geology added.

Mr. Saunders, geologist for Summa Corporation, stated that the ladder in the shaft is missing below 65 feet (personal communication). Because of the general inaccessibility of the Mabel mine, what follows is largely taken from a report by Budelman (1934):

> "Development of the Mabel Group consists of a 567 foot vertical shaft, with laterals on the 100, 200, 300, 400, 500, and 600 levels, with a winze on the vein from the 600 to the 730 level, with about 200 feet of development work on the 700 level. A total of 10, 050 feet of development work, outside of the shaft, has been performed on the property. More than half this amount is drifting, and includes considerable footage of work from intermediate levels."

Production from 1922 to 1929 inclusive amounted to 4310.3 dry tons and a metal content as follows: gold, 5526.310 ounces; silver, 396,255.99 ounces and lead, 440, 169 pounds.

The principal rocks are shales, slates, some thin beds of limestone and dark colored andesite. These rocks are so altered that they are not always easy to identify.

> "The veins are true fissure veins, having a general easterly and westerly strike, with steep dips usually to the south. Hanging wall and footwall are well defined, the former usually showing evidence of some fault movement in the plane of the vein . . . . Vein filling consist of quartz, with considerable iron oxide at times, which latter changes to pyrite and chalcopyrite with depth. Very little calcite is found, but at times barite is common, especially in the wall rocks near the veins, where occasional stringers up to several inches in width are sometimes found . . . . The veins are rarely over four feet in width and will average about two feet where stoped, with a tendency to widen with depth."

Many small cross faults, with various strikes and dips cut the veins. ". . . No large faults have been encountered, although one important one has been cut in the westerly work on these levels; the 300, 400, and 500 levels." This fault has a strong northeasterly strike with a steep dip to the northwest. There has been some silicification and mineralization along the fault, but without sufficient precious metals to prove at all profitable to mine.

> "Principal values are in silver, gold and lead, with a noticeable proportionate increase in the gold content with depth. Surface ores are oxidized, with the silver as a chloride, gold content small, and lead practically absent except in certain sections of the mine. The first sulphide ore was found in the vicinity of the 300 level and the sulphide area increases with depth, although there is still oxidation found on the 600 level. In the sulphide ore the silver and gold occur with galena, sphalerite and pyrite. Lead occurs in commercial amounts, but zinc being more spotted. No conclusion has been reached as to whether the silver and gold show any tendency to accompany any particular one of the above base metals and in fact careful sampling fails to indicate any preference . . . . The gold in the sulphide zone is not visible to the naked eye and at times is so intimately associated with the galena, sphalerite and pyrite that it cannot be detected even by panning, except by treating the panned concentrate with acid.
>
> "In both the oxidized and sulphide zone there are found occasional areas where segregated high grade gold values occur. . . . The most important of these was found between the 400 and 500 levels, where five tons of ore which averaged over $1,000 per ton in gold alone were mined. There appears to be a low grade, in places almost barren zone, in the leached or partially leached portion of the Mabel vein between the lower limits of the oxidized zone and the upper limits of the sulphide zone. A part of the 500 and 600 levels and all of the 700 level appear to have passed below this low grade zone."

A specimen collected from the ore bin was assayed by atomic absorption and found to contain: copper 0.06 percent; lead, 1.45 percent; zinc, 0.35 percent; and silver, 7.45 ounces per ton.

GARFIELD MINE

The Garfield mine is located on the southwestern slope of Mable mountain in sections 17, 20 and 21 of T7N, R33E (Plate 1 and Fig. 7). It is made up of five lode claims patented in 1887. The five claims are: Atherton, patent survey #37; Great Western, patent survey # 38; Lancashire, patent survey #39; Manchester, patent survey #40 and Bolton, patent survey #41. The five claims are owned by Summa Corporation.

The first recorded production from the mine came in 1884. In 1890 an English Company, the Hampton Plain Exploration Company, purchased the Garfield mine and built a 10 stamp mill at Garfield Springs, 9 miles south of the mine (Vanderburg, 1937, p. 33). During the 1930's lessees reworked the dump material by passing the fines through screens and according to Vanderburg (1937, p. 34) the fines had a value of $8.00 per ton. The production of the mine from 1884 to 1933 was 14,719 tons of ore valued at $584,350 (Couch and Carpenter, 1943, p. 105), but these figures do not reflect the production from 1890 to 1921. According to Budelman (1934), Boyle and Morris (1919), and Weed (1922), the production of the Garfield mine is estimated to be between $5 and $15 million. Lincoln (1923, p. 144) credits the mine with $6,000,000 of production.

Rocks exposed in the mine area are of the Gold Range Formation. The units strike northeast and dip about 50 degrees to the southeast. The elevation of the adits which comprise the mine is between 7,400 feet (2,220 meters) and 7,600 feet (2,280 meters).

The workings consist of approximately 2 miles (3 kilometers) of adits, drifts, raises and winzes, many of which are inaccessible due to caving. Three of the claims have extensive development: Great Western and Atherton (Plate 5) and Lancashire (Plates 6 & 7). The other claims for the most part have only been prospected by shallow pits. Two adits were mapped and sampled, Atherton #1 and Lancashire #1 during the summer of 1975. The Atherton #1 was the only adit having mineralization which was open at that time and the Lancashire #1 was reopened with a modest amount of digging. In the summer of 1976 several of the caved adits were reopened by Summa Corporation (Lutz, personal communication).

Mineralization in the Atherton #1 adit consists of a quartz vein which ranges from 1 foot (0.3 meters) to 4 feet (1.2 meters) and averages about 2 feet (0.6 meters) in width (Plate 5). The development work exposes the vein for about 900 feet (270 meters) and shows it to be continuous over that distance. The vein is a fissure vein with the north rib in places having from 2 inches (5 centimeters) to 4 inches (10 centimeters) of clay gangue. The major portion of the vein, about 600 feet (180 meters) trends N70E and dips between 30 and 80 degrees to the northwest. The remainder, about 300 feet (90 meters) nearest the portal, trends N80°W and dips between vertical and 50 degrees to the northeast. The vein filling consists of fractured, in places crushed, quartz stained with iron oxides and dendrites of manganese oxides. The quartz encloses limonite pseudomorphs after pyrite, up to 3 millimeters across. Several specimens were X-rayed in an attempt to determine what minerals were present, but only quartz and pyrite were detected. Specimens collected from the adit were assayed by atomic absorption, the highest of which contained: copper, 0.02 percent; lead, 0.01 percent; zinc, 0.01 percent and silver, 1.11 ounces per ton.

Wall rocks in the adit are fine-grained clastic sediments and andesite flows, both of which show varying degrees and types of alteration. Alteration specimens were mainly collected from the cross cut connecting the Atherton #1 adit with the Great Western #1 adit; however, one specimen was taken in the room across from the winze at the east end of the Atherton #1 adit. The cross cut contains no mineralization and it was felt that by sampling rocks in the cross cut the alteration could be studied over a distance. Specimens collected in the cross cut were taken at 20 feet (6 meters), 10 feet (3 meters), 5 feet (1.5 meters), 3 feet (0.9 meters) and 1 foot (0.3 meters) away from the vein in the Atherton #1 adit. Both hand specimens and thin sections show the effects of increasing alteration nearing the vein. The specimen collected 20 feet (6 meters) from the vein is a spotted hornfels, dark gray-green in color, with dark spots 0.5 millimeters across. The rock exhibits subconchoidal fracture, with limonite stains on fracture surfaces. A thin section of this rock reveals that the dark spots are chlorite and sericite, but mainly chlorite. The matrix consists of secondary biotite, quartz and sericite. Hand specimens become lighter in color, with a reduction in the size and numbers of chloritic dark spots, when approaching the vein. One foot (0.3 meters) from the vein the rock is light tan and no dark spots remain. This rock is highly fractured, with iron oxide and manganese oxide stains on the fracture surfaces. Thin sections of the specimens approaching the vein reveal that secondary biotite increases up to a point, between 5 feet (1.5 meters) and 10 feet (3 meters) from the vein, then it begins to decrease. At one foot (0.3 meters) from the vein no secondary biotite remains. Sericite and secondary quartz increase toward the vein, while chlorite decreases. Between 3 feet (0.9 meters) and 1 foot (0.3 meters) pyrite is added to the wall rock. At one foot (0.3 meters) from the vein the rock consists of sericite, quartz and limonite pseudomorphs after pyrite.

The specimen collected at the east end of the adit shows the effects of alteration on two rock types, andesite and an argillite. Apparently this rock was a highly argillacieous rock with andesite fragments up to 2 centimeters across. The specimen was collected about 20 feet (6 meters) away from the vein. The argillaceous portion, now a spotted hornfels, shows the same type and degree of alteration as the specimen collected 20 feet (6 meters) away from the vein in the cross cut. In thin section the andesite fragments are altered sufficiently so that of the original minerals only plagioclase can be recognized. The plagioclase is being altered to sericite and the groundmass to sericite and secondary biotite.

The Lancashire claim has two adits, but only the Lancashire #1 adit was entered. The Lancashire #1 (Plates 6 and 7) consist of about

1500 feet (450 meters) of drifts, cross cuts, and inclines, which expose quartz veins similar to the one seen in the Atherton #1 adit. The map indicates an area of stopes and inclines which are inaccessible because of back filling. The veins are fissure veins which trend northwest and dip to the southwest. They appear to be short and discontinuous and are bounded on one side by a fault. The vein fillings consist of fractured and sheared quartz stained by iron oxide and manganese oxide. The veins range from 2 inches (5 centimeters) to 8 inches (20 centimeters) in width. Apparently high values were obtained from the sheared quartz veins, as indicated by the number of stopes. A specimen collected from the vein and assayed by atomic absorption was found to contain: copper, 0.02 percent; lead, 0.18 percent; zinc, 0.02 percent and silver, 1.34 ounces per ton. Fire assay of the same specimen showed: gold, trace; silver, 4.66 ounces per ton.

The map of the Great Western adits indicates the trend of the vein and extent of stoping along it (Plate 5). The vein strikes between N85°E and N75°E and dips between 50 and 85 degrees to the northwest. The vein is exposed about 1000 feet (300 meters) along strike in the Great Western #1 adit and apparently good values were obtained in several locations along the vein as indicated by the stopes. It also appears that the workings were somewhat more extensive than indicated by the map because some areas are caved or backfilled. Two specimens were collected, one from the dump of the Great Western #2 and the other from the dump of the Great Western #3 and both samples were assayed by atomic absorption and fire. The atomic absorption assay showed the specimen from the Great Western #2 contained: copper, 0.10 percent; lead, 0.19 percent; zinc, 0.63 percent and silver, 1.90 ounces per ton. Fire assay of this same specimen showed: gold, trace; silver, 7.90 ounces per ton. The atomic absorption assay from the Great Western #3 contained: copper, 0.12 percent; lead, 0.31 percent; zinc, 0.41 percent and silver, 42.93 ounces per ton. Fire assay of this specimen showed: gold, 0.006 ounces per ton; silver, 58.68 ounces per ton.

MISCELLANEOUS PROSPECTS

The miscellaneous prospects fall into three groups: quartz veins, copper veins and barite float. These groups will be discussed in a general way.

Ten quartz veins occur as single veins 4 inches (10 centimeters) to 3 feet (0.9 meters) wide and exposed along strike up to 50 feet (15 meters). The only visible sulphide mineral is pyrite; however, the veins are normally so highly oxidized that the quartz is iron stained and contains pseudomorphs of limonite. The strike of most of these veins are responsible for the scatter shown on the rose diagram of the quartz veins (Fig. 10), being randomly oriented.

The copper veins occur also as single veins about 2 inches (5 centimeters) wide. The only sulphide copper mineral, chalcopyrite, was found at a copper prospect about 1 mile (1.6 kilometers) northwest of the Bluelight mine (Fig. 7). The strike of these veins are similar to the rest of the copper veins in the district.

Only one occurrence of barite was found and that was as float about 0.5 mile (0.8 kilometers) south of the Mabel mine (Fig. 7). The pieces ranged in size up to 8 inches (20 centimeters) across of white crystalline barite.

SUMMARY

Two general types of mineralization are recognized in the district: silver-gold in quartz veins and copper in igneous metamorphic deposits. These two types of mineralization appear unrelated and possibly represent different periods of mineralization.

The quartz veins at the Mendora, Mabel and Garfield mines are generally steeply dipping, within 20 degrees of the vertical with few dips less than 50 degrees. The strikes of the quartz veins in the district are plotted on rose diagram (Fig. 10). The diagram reveals that the bulk of the quartz veins in the district strike between N60°W and N75°E, with the highest concentration being between N60°W and N80°W. The major veins in the district strike between N60°W and N75°E. The veins cross cut bedding and in places dip in the opposite direction to the bedding. The length of the veins and vein systems range from at least 500 feet (150 meters) at the Mabel mine to 1000 feet (300 meters) at the Mendora and Garfield mines. The veins are exposed vertically for some distance at the various mines: 250 feet (75 meters) at the Garfield; 200 feet (60 meters) at the Mendora and 700 feet (210 meters) at the Mabel. The width of the veins ranges from 2 inches (5 centimeters) to 4 feet (1.2 meters) with the hanging wall and foot wall well defined. The veins occur as fissure fillings and many show signs of post ore movement. With the exception of the fault in the Atherton #1 about 500 feet (150 meters) east of the portal, post ore faulting has displaced the veins only a few feet.

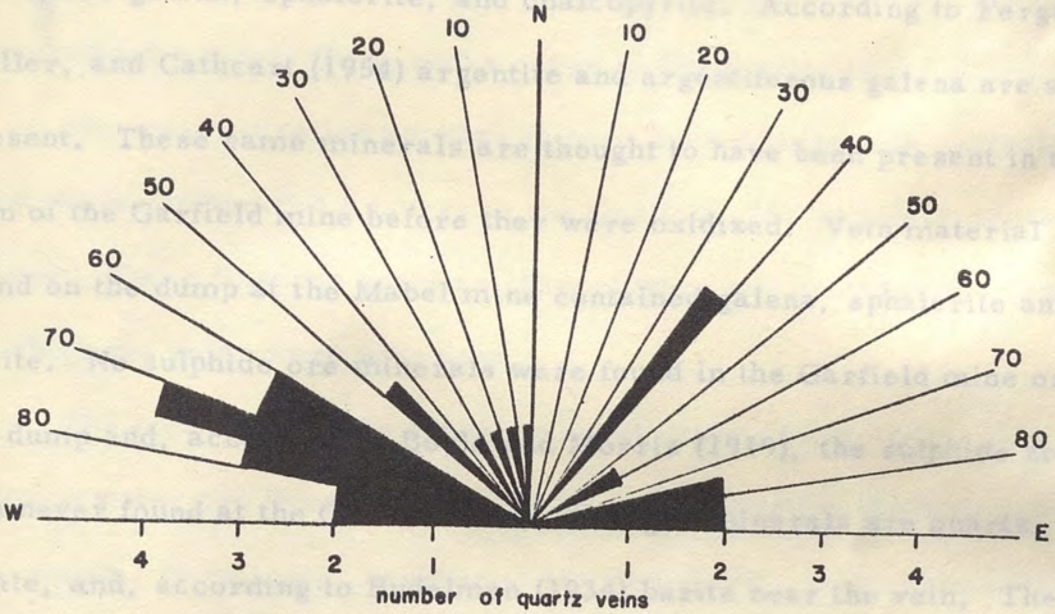

Figure 10. The frequency of strikes, quartz veins in the Garfield mining district.

The vein quartz is both aphanitic and phaneritic. The finer grained variety is a milky white, while the coarser-grained variety becomes clearer as the size of the crystals increases.

The hypogene ore minerals at the Mabel mine reported by Budelman (1934) are galena, sphalerite, and chalcopyrite. According to Ferguson, Muller, and Cathcart (1954) argentite and argentiferous galena are also present. These same minerals are thought to have been present in the vein of the Garfield mine before they were oxidized. Vein material found on the dump at the Mabel mine contained galena, sphalerite and pyrite. No sulphide ore minerals were found in the Garfield mine or on the dump and, according to Boyle and Morris (1919), the sulphide zone was never found at the Garfield mine. Gangue minerals are quartz, pyrite, and, according to Budelman (1934) barite near the vein. The veins strike between N60°W and N80°W. The level of oxidization at the Mabel and Garfield mines is in excess of 300 feet (90 meters).

The ore mineralogy, gangue minerals, strike of the veins and level of oxidization at the Mendora mine are different than those features found at the Garfield and Mabel mines. The hypogene ore minerals are jamesonite, stibnite and pyrargite with a gangue of quartz, pyrite and calcite. The veins strike between N55°E and N65°E, and sulphide minerals remain within 100 feet of the surface.

The Mendora, Mabel and Garfield mines have similar types of alteration in the rocks of the Gold Range Formation: sericitic alteration, with increasing amounts and quartz, pyrite and sericite nearing the veins.

There appears to have been no stratigraphic control of the mineralization since both the limestone of the Luning Formation and the rocks of the Gold Range Formation are mineralized at the Mendora mine. At the Garfield and Mabel mine only rocks of the Gold Range Formation are mineralized but only these rocks occur in the vicinity of the mines.

The mineralization appears to have been structurally controlled by a series of parallel fissures at the Garfield, Mabel and Mendora mines. These fissures acted as channel ways and provided open spaces in which the veins were deposited.

The combination of original mineralization, brecciation, and surface water are thought to have been responsible for the high grade ore zones. Here again, because of inaccessibility, these conclusions are based on map interpretation and not direct observation. Brecciation of the veins and wall rocks would have increased their porosity, allowing surface water to percolate downward. Discussions of supergene enrichment of silver, Lindgren (1933), Ferguson (1944), and Park and Mac Diarmid (1970) indicate that the weathering of pyrite generates a solution of ferric sulfate, which will break down sulfides of silver, lead and zinc. The released silver would travel downward by meteoric water. The presence of chloride, commonly in surface water would cause precipitation of the silver chloride, cerargyrite at some depth below the surface.

The age of mineralization is thought to be Tertiary and possibly associated with intermediate volcanic activity. Many of the precious metal deposits in the western part of the Great Basin and in particular along Walker Lane, (Silberman, et al., 1976), are Pliocene and Miocene. Gold and silver bearing quartz veins, (Silberman et al., 1975) at Camp Douglas have been dated at 15 million years old. There the mineralization is related to Miocene intermediate volcanic activity.

This type of mineralization displays many of the characteristics of epithermal deposits. These characteristics are gangue minerals, open space filling, banded veins, brecciated veins, sericitic alteration near the veins and Tertiary volcanic activity near by.

The copper mineralization occurs in shear zones replacing limestone and as fissure fillings in clastic rocks. The ore minerals are oxidized copper products at the exposures. The bulk of the veins strike between N60^{o}E and N90^{o}E, with the largest concentration being between N70^{o}E and N85^{o}E (Fig. 11). With the exception of the copper shows near the Mendora mine, all the copper prospects and mines lie along a N - W trending line. Within the district at one end of the line is the Bataan mine and at the other end is the Bluelight mine with two copper prospects between (Fig. 7). Leaving the district and going about one mile (1.6 kilometer) to the southeast of the Bluelight mine to the Silver Side mine, on the southeast side of the stock, the copper line can be continued. This line of copper occurrences appears to lie along one of the NW trending lineaments, which was discussed in the local structure section.

The host rocks at the Bataan and Bluelight mines are limestone of the Luning and Dunlap Formations and exhibit similar types of alteration.

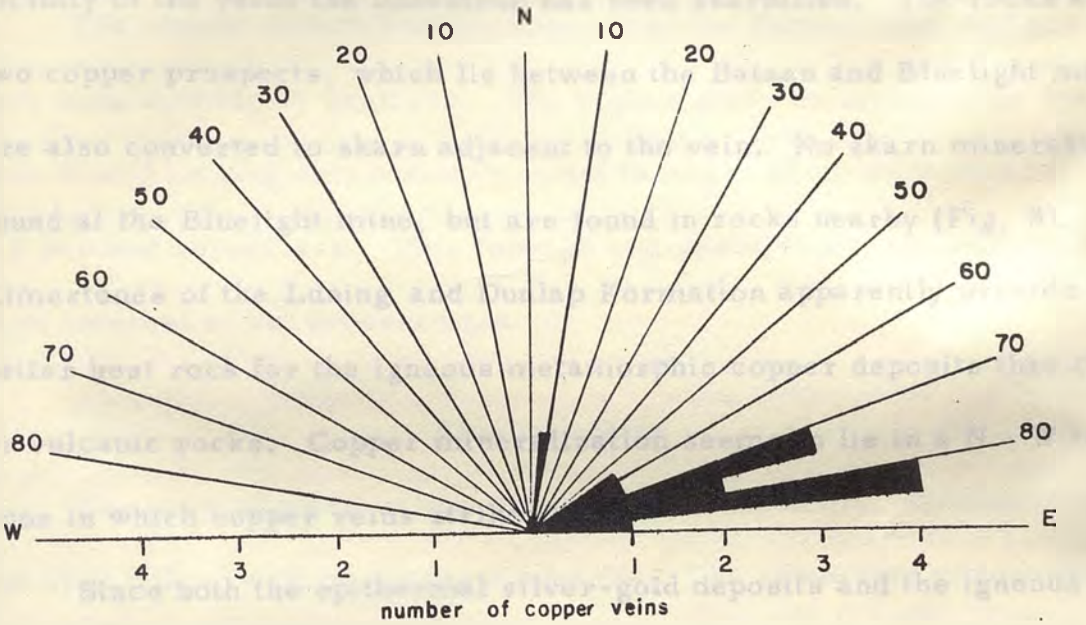

Figure 11. The frequency of strikes, copper veins in the Garfield mining district.

The limestones near mineralization have been recrystallized, bleached and have a sandy texture. The Luning limestone, which has more extensive outcroppings, shows partial recrystallization for some distance beyond known mineralization. At the Bataan mine in the immediate vicinity of the veins the limestone has been skarnified. The rocks at the two copper prospects, which lie between the Bataan and Bluelight mines, are also converted to skarn adjacent to the vein. No skarn minerals are found at the Bluelight mine, but are found in rocks nearby (Fig. 8). Limestones of the Luning and Dunlap Formation apparently provide a better host rock for the igneous metamorphic copper deposits than clastic or volcanic rocks. Copper mineralization seems to lie in a N - W trending zone in which copper veins strike N - E.

Since both the epithermal silver-gold deposits and the igneous metamorphic deposits are found at or near the surface, presumably the copper deposits are older than the silver-gold deposits. Epithermal deposits are emplaced near the surface and igneous metamorphic deposits are deep seated events. Therefore to attain approximately the same present elevation, the igneous metamorphic deposits would require more time for erosion. The igneous metamorphic deposits are thought to be Cretaceous in age and associated with intrusives of the same period.

POTENTIAL FOR ORE

The ore potential of the district will be estimated by estimating the potential of each mine.

Bataan Mine

The copper mineralization exposed at the Bataan mine appears to have been thoroughly explored. The higher grade mineralization has been mined leaving only a rather small tonnage, about 4500 tons of 2.2 percent copper ore. This tonnage and grade seems insufficient to be of interest at the present time.

Bluelight Mine

The mine appears to have been explored by drifts, bulldozer cuts and drill holes, with no apparent success. The remaining mineralization seems to be restricted to veins exposed at the surface by the bulldozer cuts. It is estimated that these veins contain about 800 tons of 1.3 percent copper ore, which is of little interest today.

Mendora Mine

This mine also seems to have been thoroughly explored. Available information does not include assays or other pertinent data concerning the adits. Therefore the estimate of ore at the Mendora mine is based on and pertains to the workings at the shaft. The mine is estimated to have about 2400 tons of "ore" remaining containing about 1.49 ounces of silver per ton. This tonnage and grade are of little interest at the present time.

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Mendora Mine

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Mabel Mine

The available information concerning the mine consists of a report by Budelman (1934) and maps of the underground workings. These sources suggest that considerable "ore" remains; however, the grade is uncertain. It is estimated that the mine may contain as much as 45,000 tons of "ore" averaging less than 0.15 ounces of gold per ton and 10 ounces of silver per ton. It is felt that this remaining mineralization is probably of too low a tonnage and grade to be of interest today.

Garfield Mine

Accessible mineralization exposed in the Atherton #1 adit and the Lancashire #1 adit is estimated at about 3000 tons of "ore" averaging 0.3 ounces of gold per ton and 1 ounce of silver per ton. This tonnage and grade is also insufficient to be of interest at the present time.

EXPLORATION SUGGESTIONS

Silver-gold deposits in the Garfield district are characteristically small, high grade, and enriched near the surface. Veins of the high grade character which have been found are mined out, leaving only the lower grade ores. There seems to be nothing to indicate any large deposits, such as porphyry copper, in the district. The areas of known mineralization and those proposed, are small deposits. Therefore, without at least the suggestion of a large deposit the future potential of the district appears rather limited.

The best chance for discovering a new silver-gold deposit lies in the area between the Lancashire and Atherton claims. This encompasses the Manchester and Bolton Claims and unclaimed land to the south of them. The vein systems at the Mabel and Garfield mines are of similar character and it seems possible that they are part of the same vein system. There is no evidence of any serious attempt to explore the Manchester and Bolton claims, except by shallow diggings. There is good reason to believe that at least the vein in the Atherton #1 extends some distance to the west (Plate 5). About 500 feet (150 meters) from the portal the vein has been truncated by a fault, which has down dropped the western side. This same situation occurs in the Atherton #2 and may have occurred to the Great Western vein as well. Therefore it is possible that ore similar to that mined at the Mabel mine, Atherton and Great Western claims exists in the untested ground between them. If mineralization could be found comparable to that of the Mabel mine, then about 4000 tons of ore containing 1.28 ounces of gold per ton and 91 ounces of silver per ton might be expected.

The copper mineralization in igneous metamorphic deposits of the district are small, but the ore at the Bluelight mine was apparently high grade. The Bluelight mine contained the only copper mineralization of importance thus far discovered in the district and it is mined out.

Excluding the copper shows in the vicinity of the Mendora mine, the copper mineralization occurs along a line with the Bataan mine at one end and the Bluelight mine at the other end (Fig. 7). Between the two mines are two copper prospects, one on either side of a syncline of the Luning limestone. The best target for copper exploration is along the line of copper shows and in particular in the area of the above-mentioned syncline. If copper mineralization exists here it is probably small, but possibly high grade.

The third and final exploration target is in the area (Fig. 7), where white crystalline barite was found. The barite in and of itself probably is not significant, but the barite quartz vein association reported by Budelman suggests the possibility of a quartz vein near the surface.

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